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Hosek et al.

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(45) **Date of Patent: Oct. 24, 2017**

(54) **ROBOT DRIVE WITH RADIALLY ADJUSTABLE SENSOR CONNECTION**

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(73) Assignee: **Persimmon Technologies Corporation**, Wakefield, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 791 days.

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(22) Filed: **Jan. 18, 2013**

(65) **Prior Publication Data**

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(Continued)

(51) **Int. Cl.**

H02K 5/128	(2006.01)
H02K 21/44	(2006.01)
H02K 41/03	(2006.01)
H02K 5/00	(2006.01)
H02K 9/22	(2006.01)
H02K 5/22	(2006.01)
H02K 3/30	(2006.01)
H02K 3/44	(2006.01)
H02K 15/12	(2006.01)

(52) **U.S. Cl.**
CPC ***H02K 5/128*** (2013.01); ***H02K 5/00*** (2013.01); ***H02K 5/225*** (2013.01); ***H02K 9/22*** (2013.01); ***H02K 21/44*** (2013.01); ***H02K 41/033*** (2013.01); *H02K 3/30* (2013.01); *H02K 3/44* (2013.01); *H02K 15/12* (2013.01); *Y10S 901/23* (2013.01)

(58) **Field of Classification Search**
CPC . H02K 11/0015; B25J 9/024; H01L 21/67742
USPC .... 310/71, 68 B; 414/744.5
See application file for complete search history.

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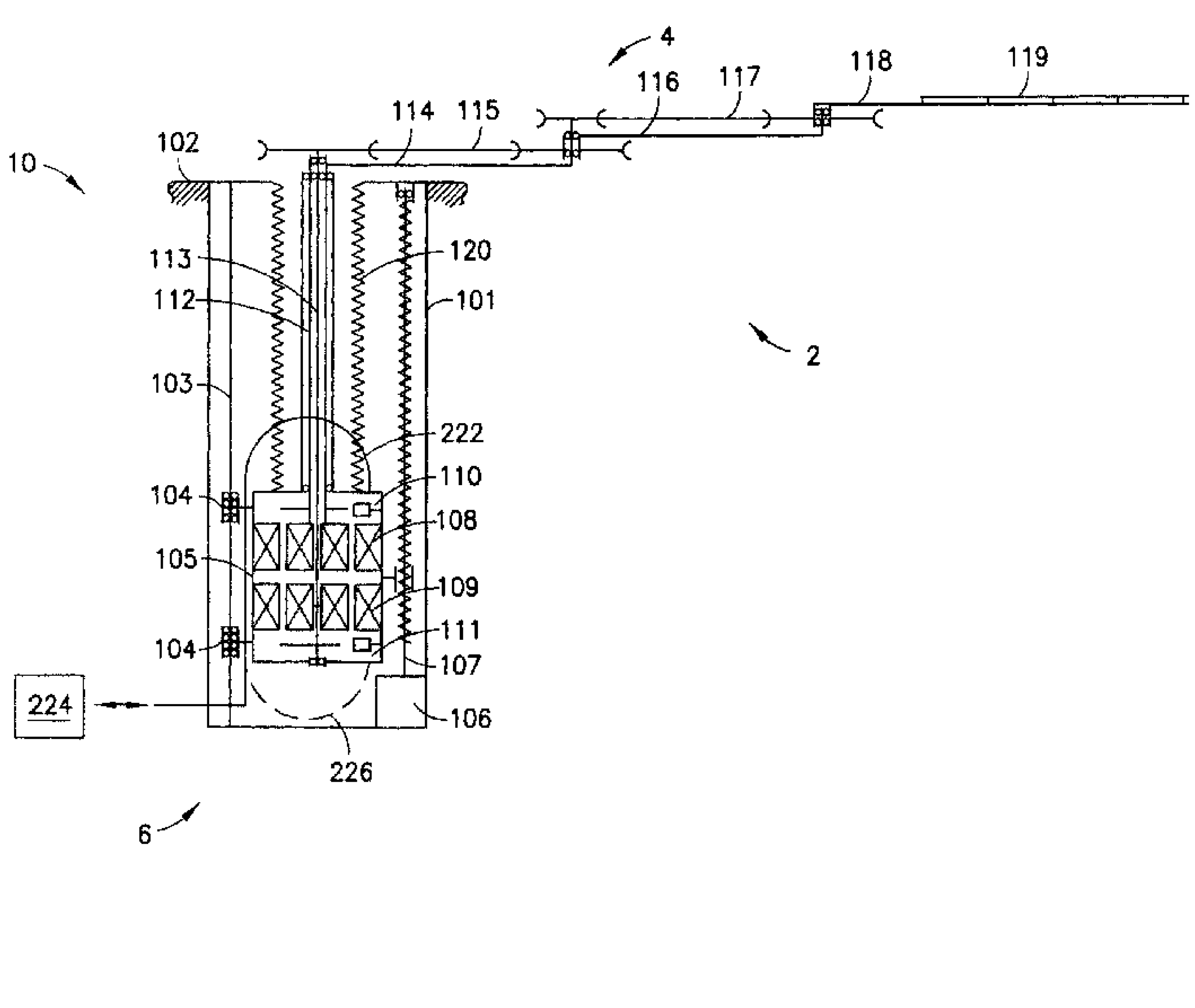
Primary Examiner — Thanh Lam
(74) *Attorney, Agent, or Firm* — Harrington & Smith

(57) **ABSTRACT**

A substrate transport apparatus including a drive section and a first movable arm assembly. The drive section includes a first motor. The first motor includes a stator and a passive rotor. The first movable arm assembly is connected to the first motor. The substrate transport apparatus is configured for the first movable arm assembly to be positionable in a vacuum chamber with the passive rotor being in communication with an environment inside the vacuum chamber.

18 Claims, 14 Drawing Sheets



Related U.S. Application Data

(60) Provisional application No. 61/627,030, filed on Sep. 16, 2011, provisional application No. 61/683,297, filed on Aug. 15, 2012.

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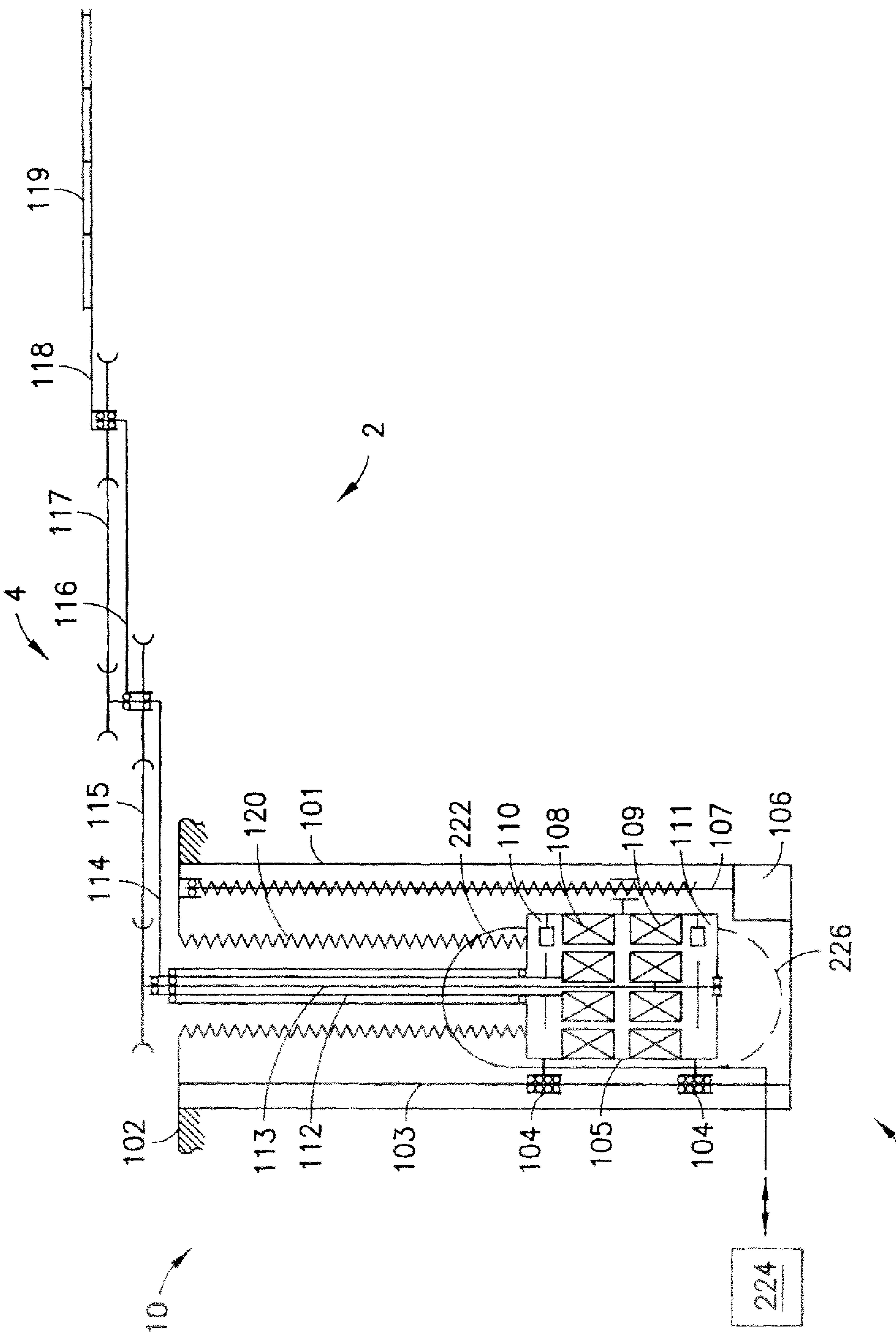
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FIG.1

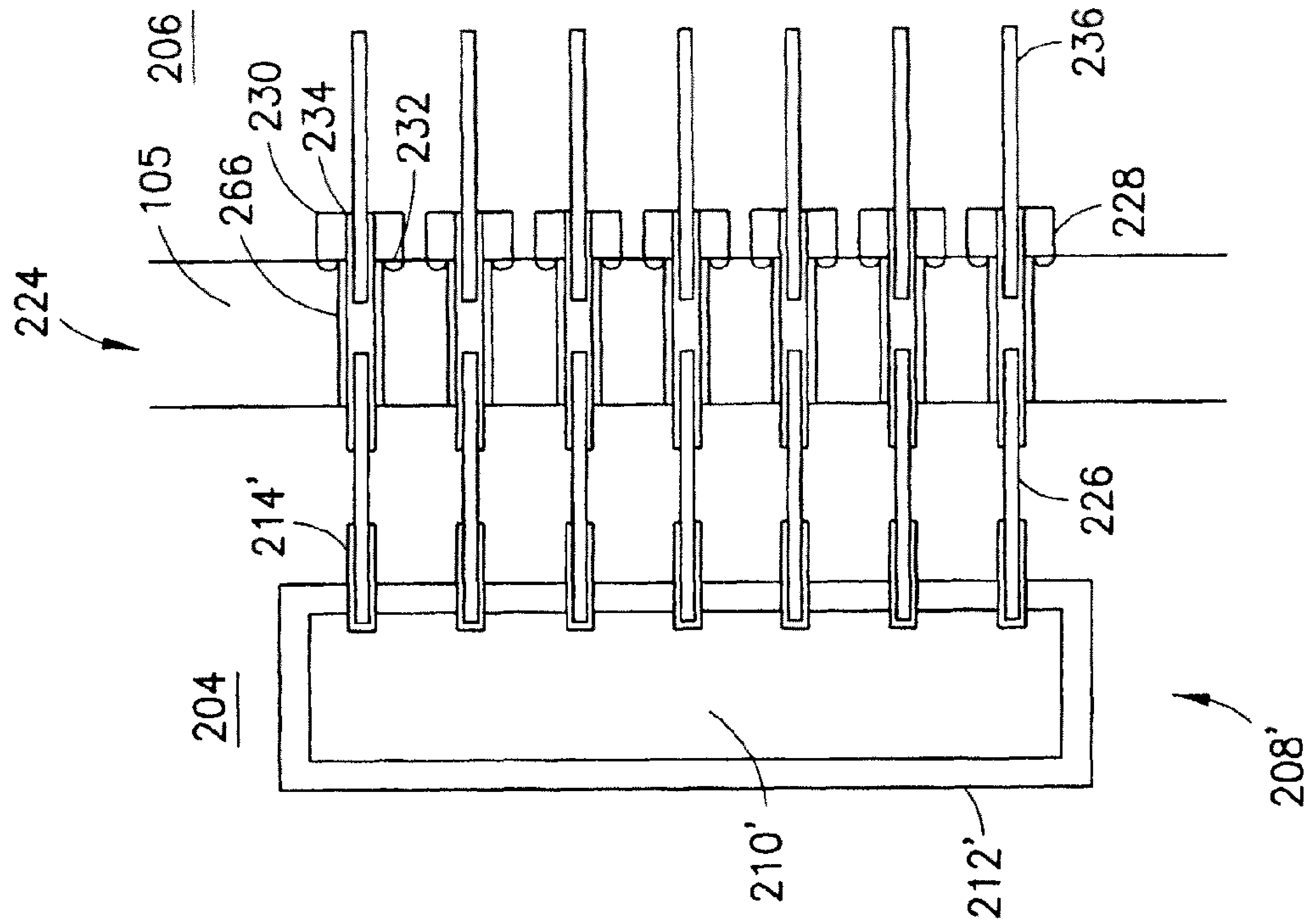

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FIG.3A

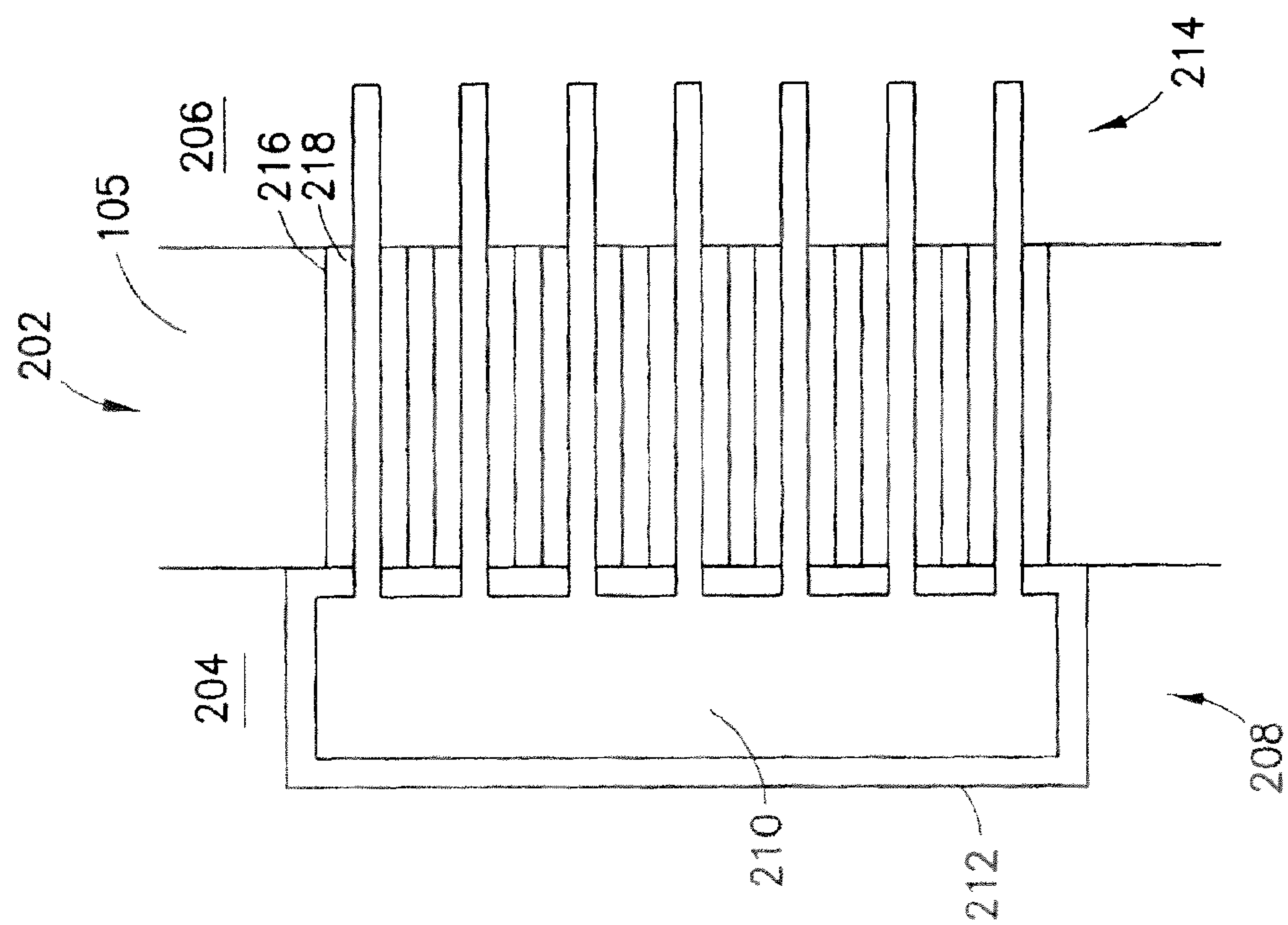

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FIG.2

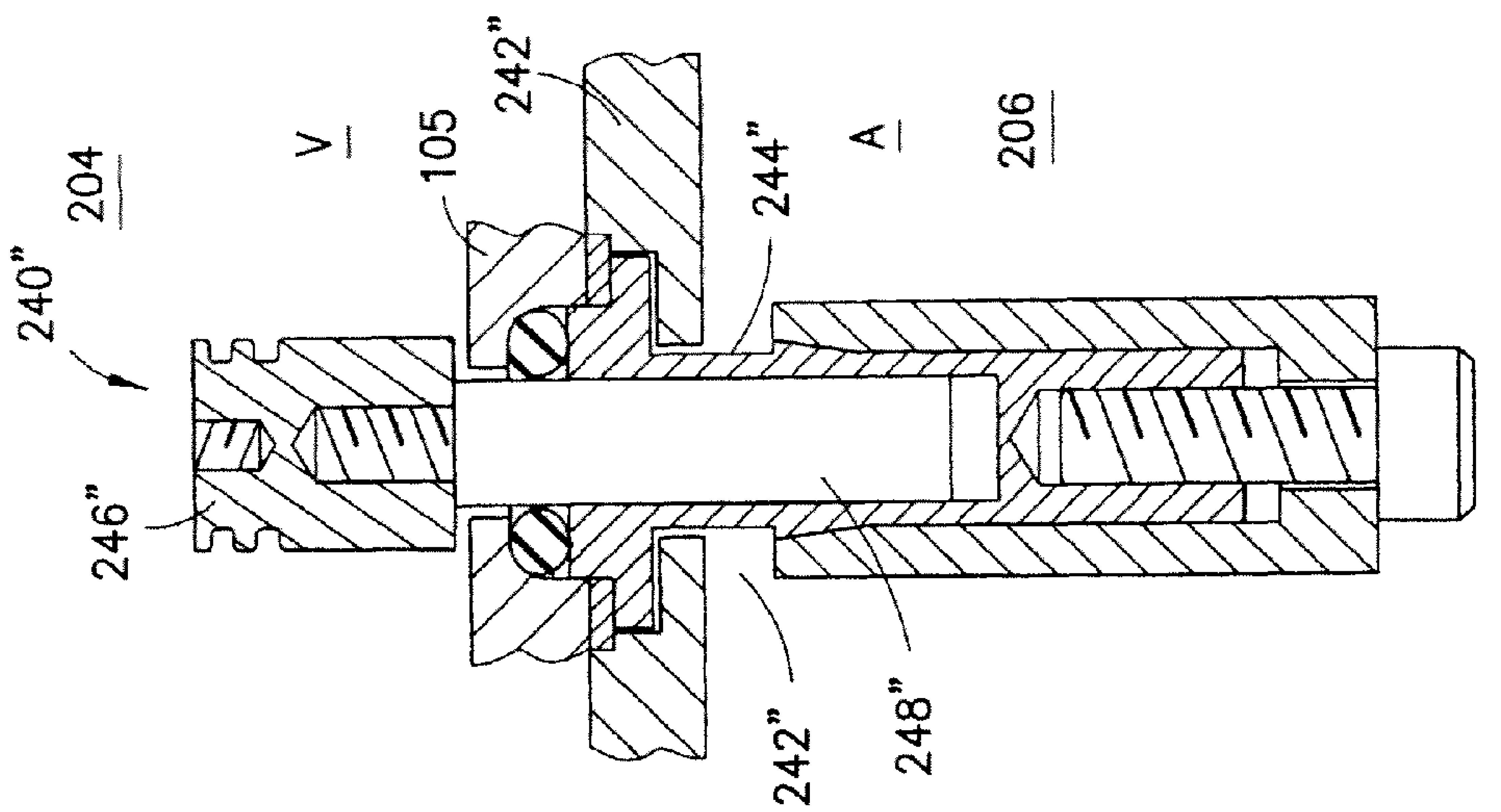


FIG.3D

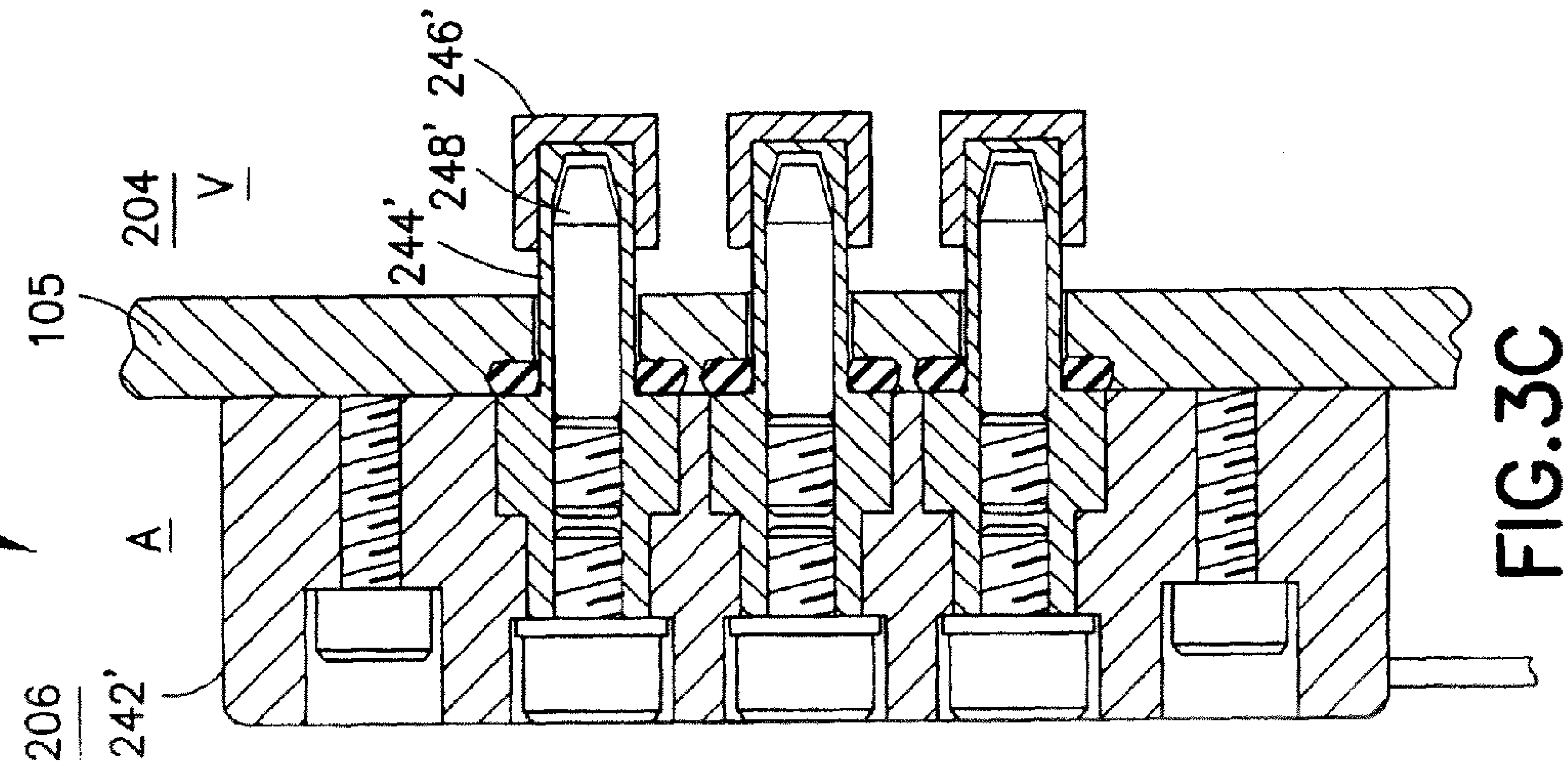


FIG.3C

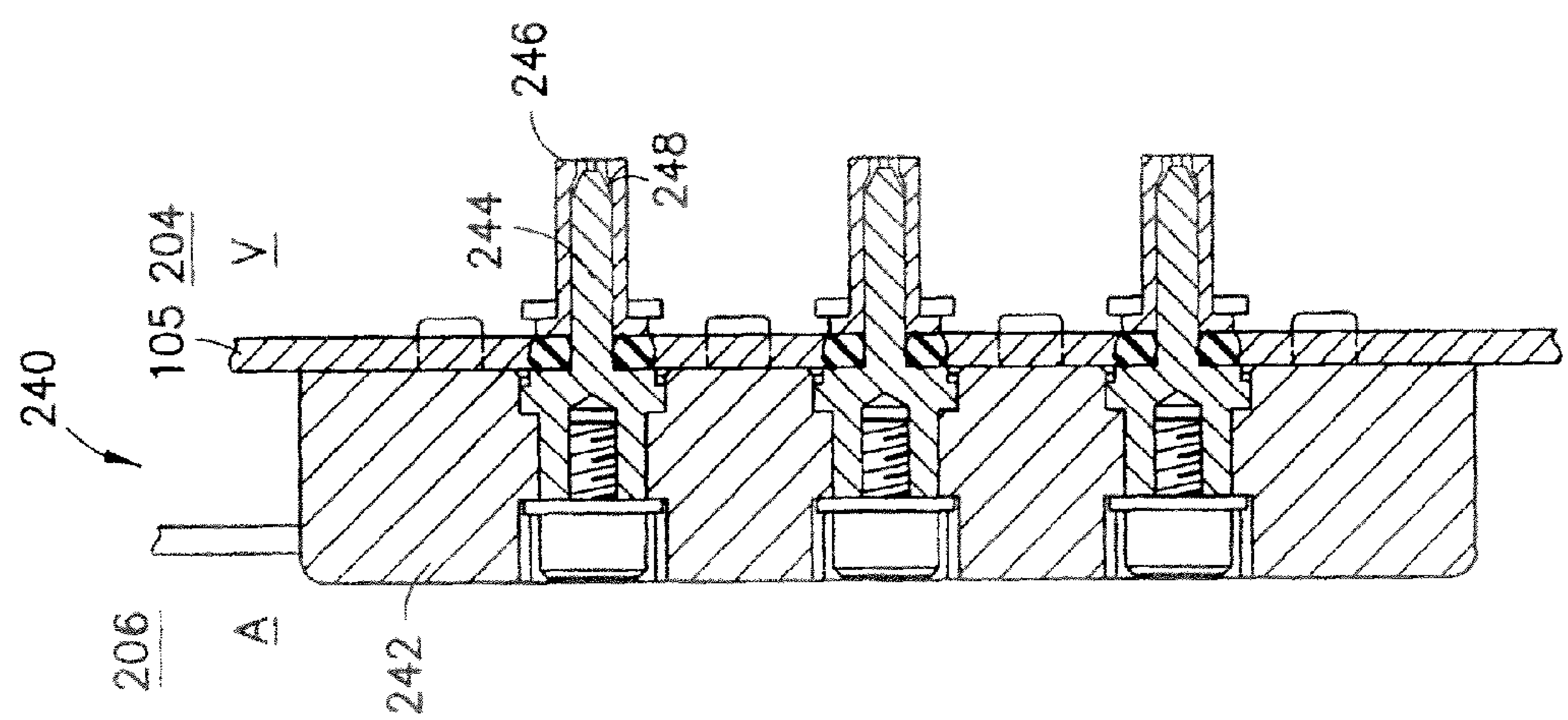
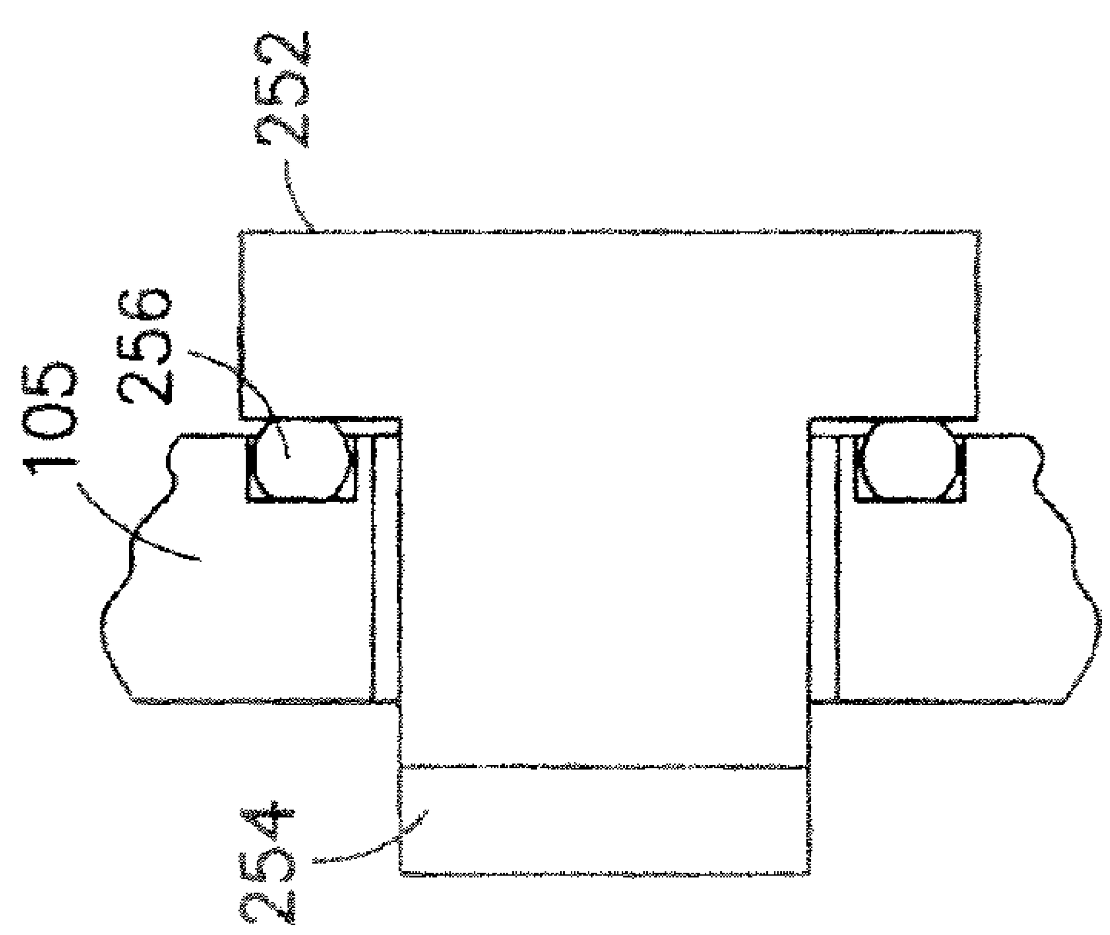


FIG.3B



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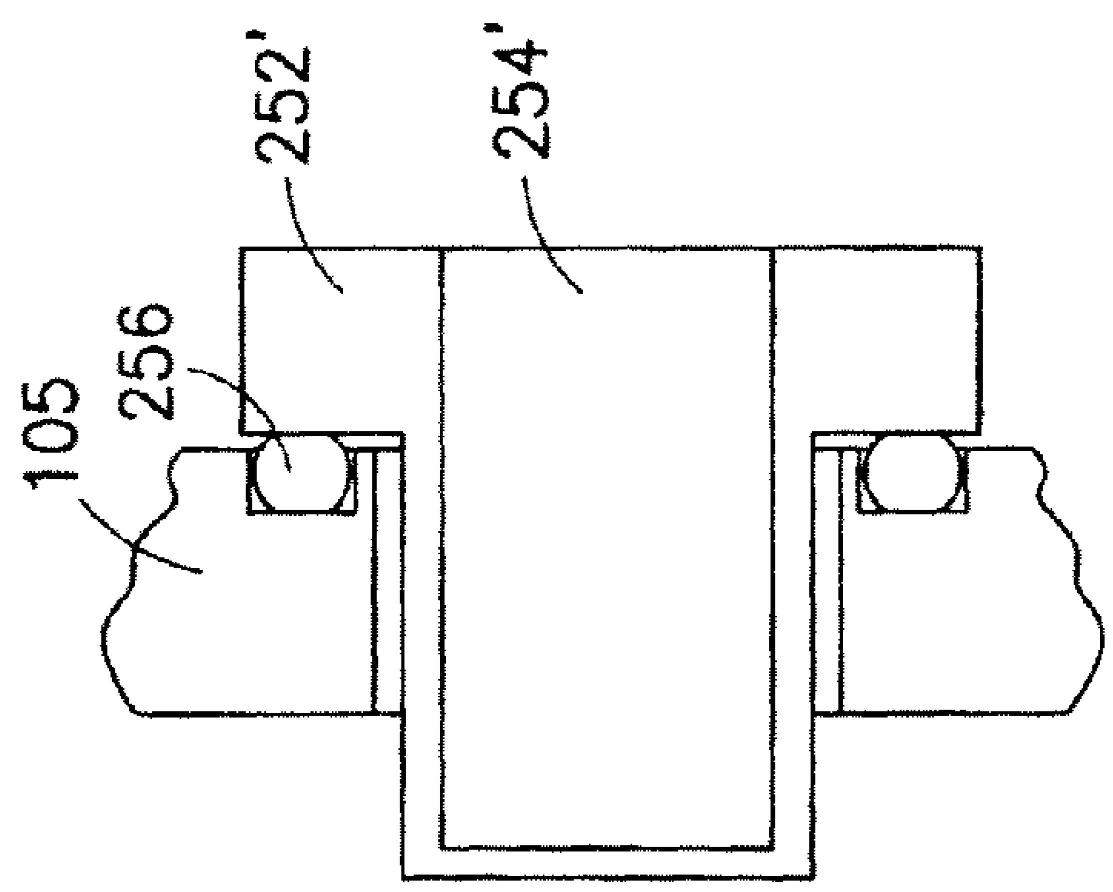
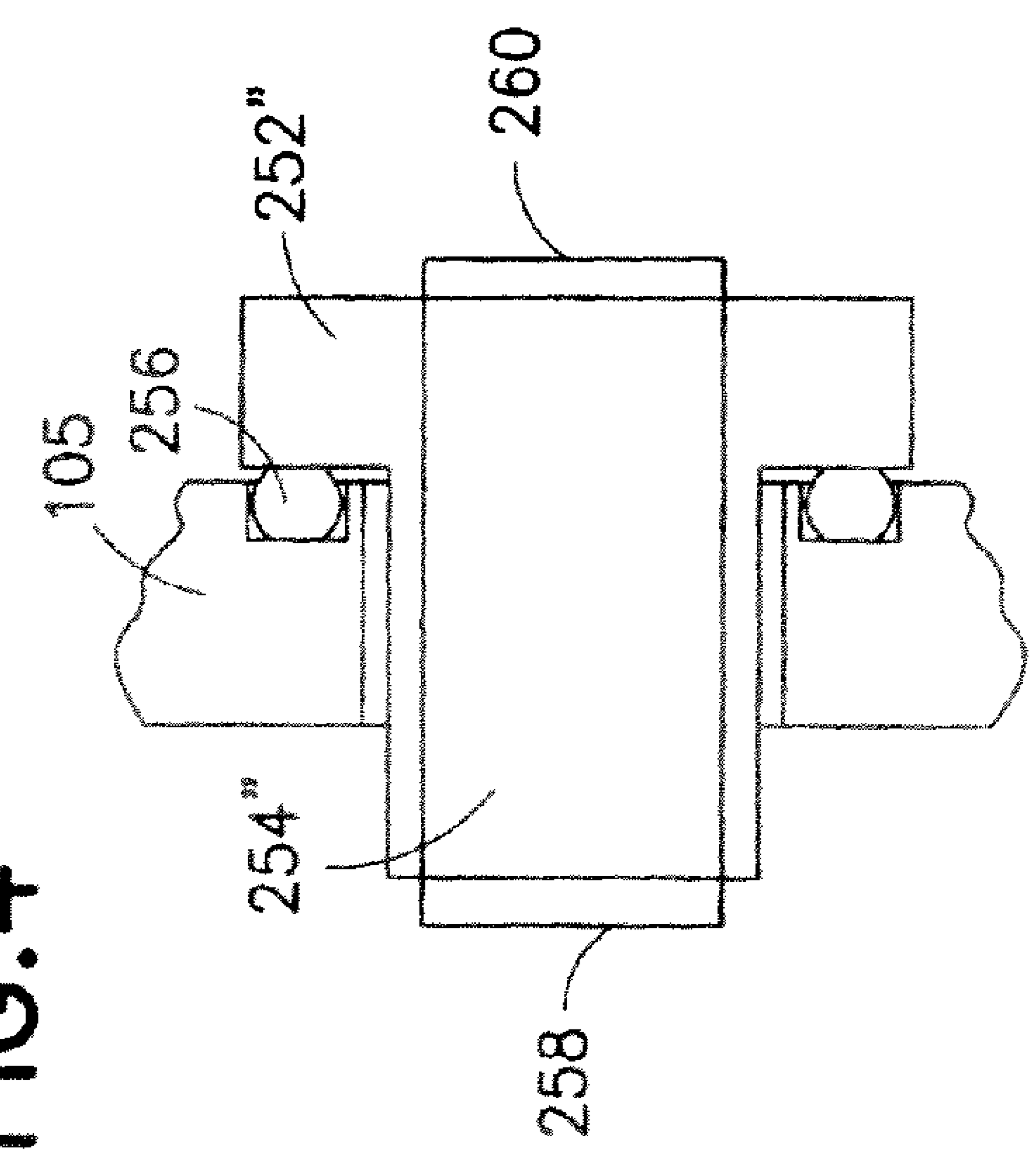


FIG.5



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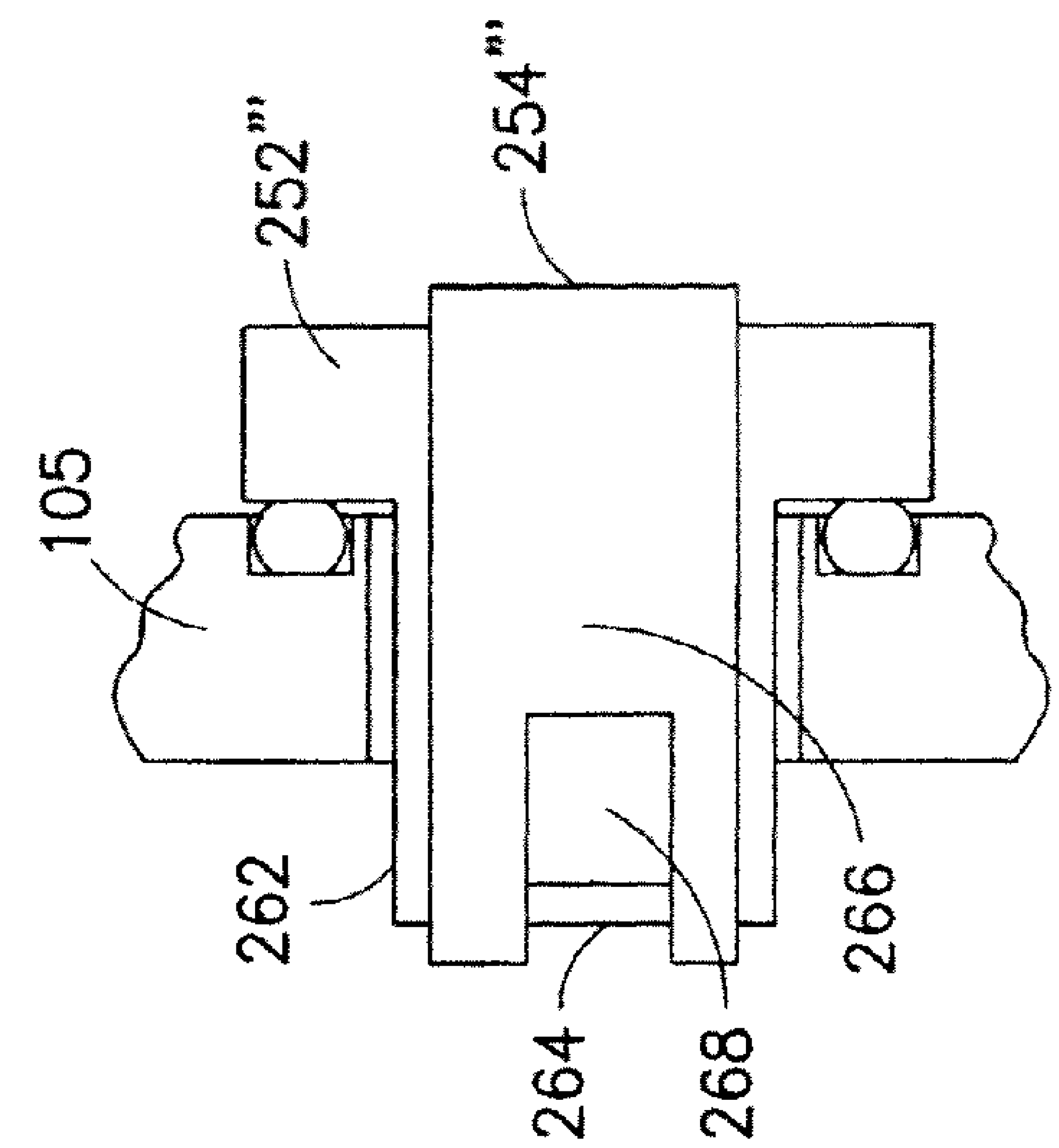

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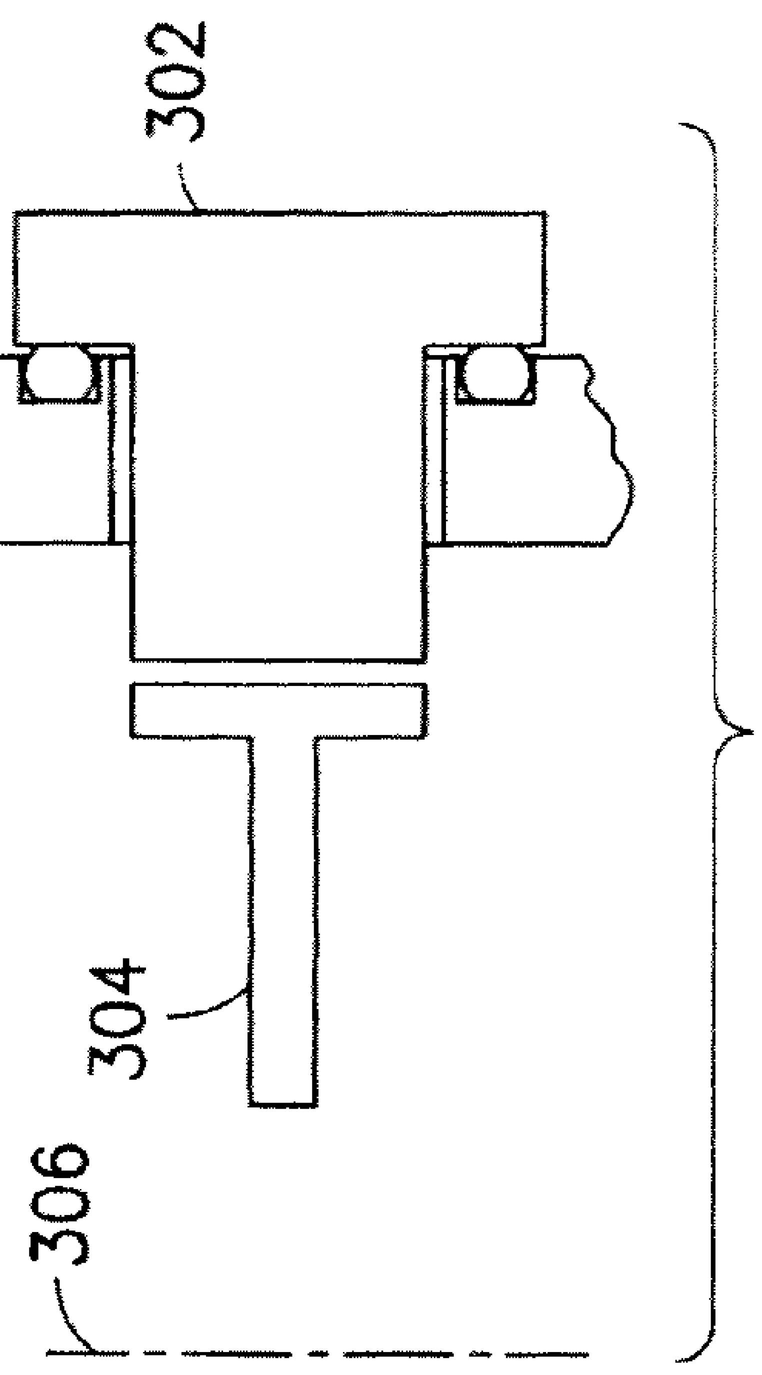

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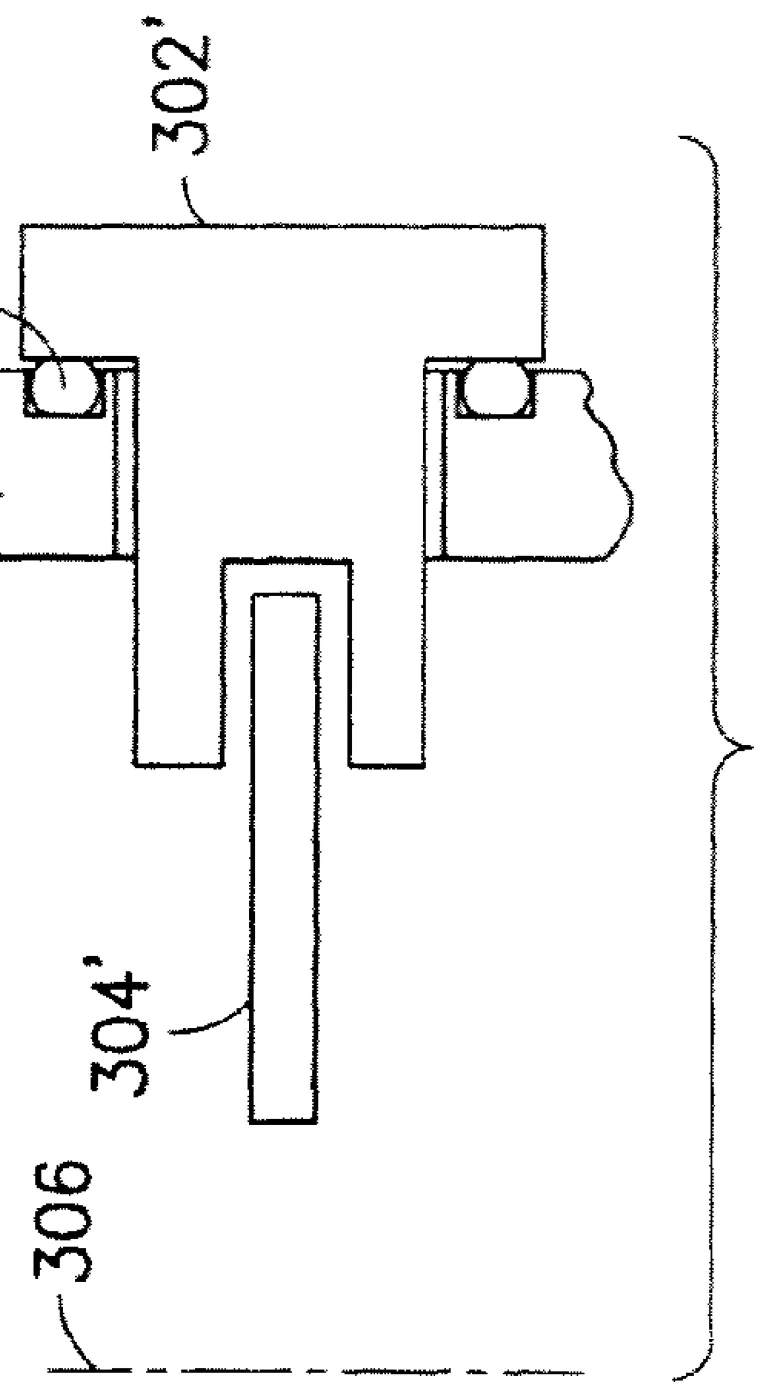

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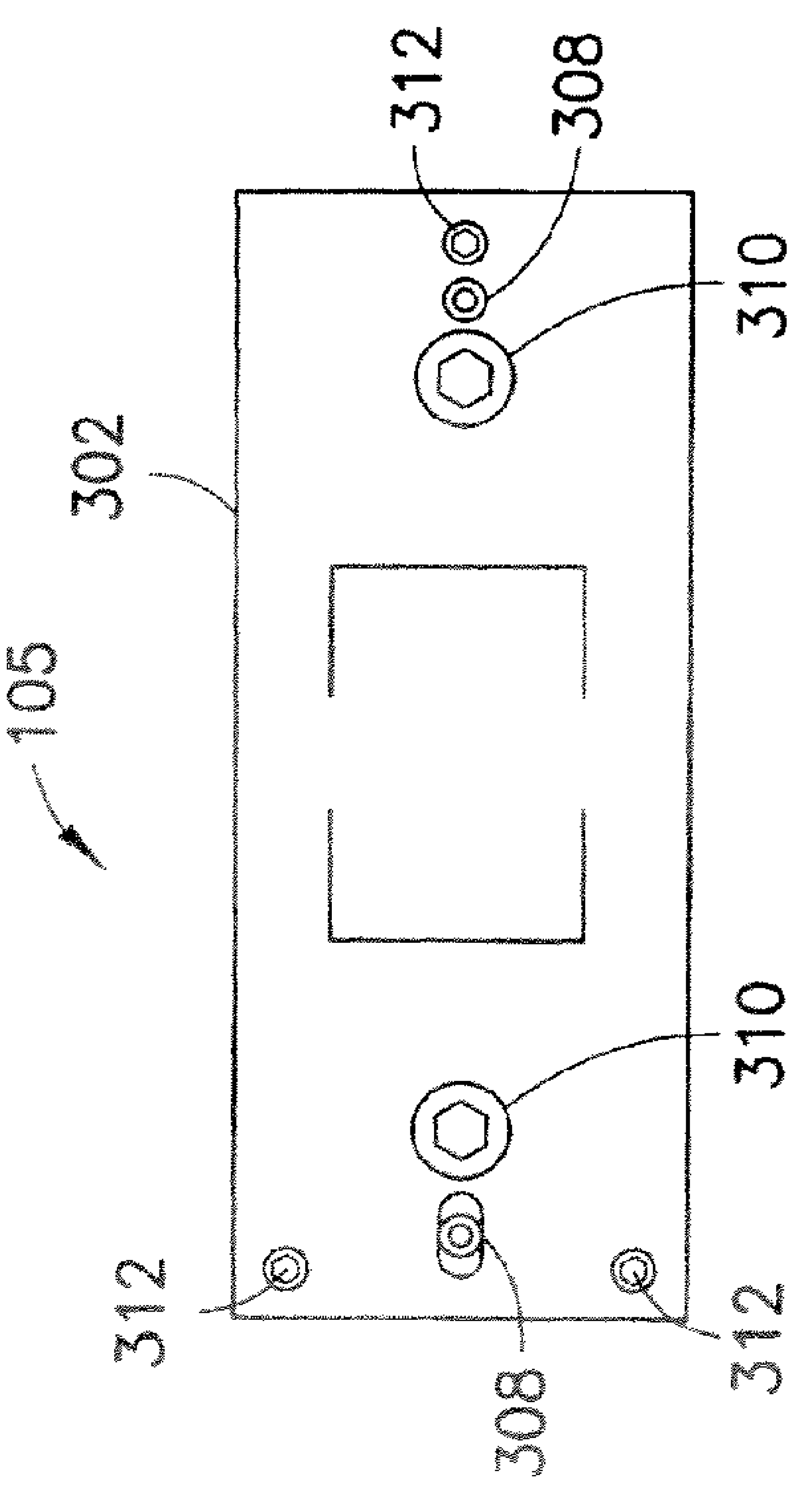

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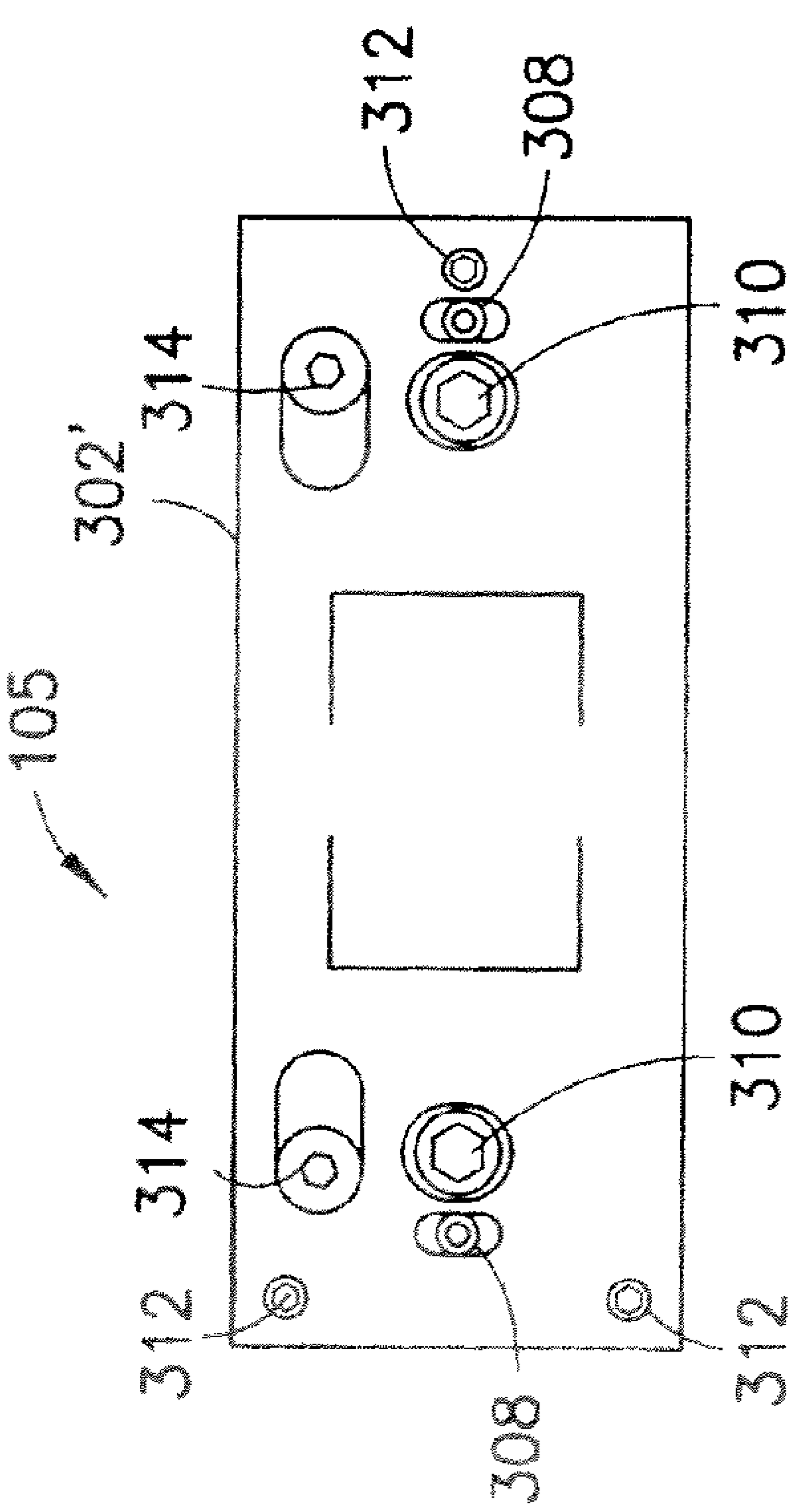

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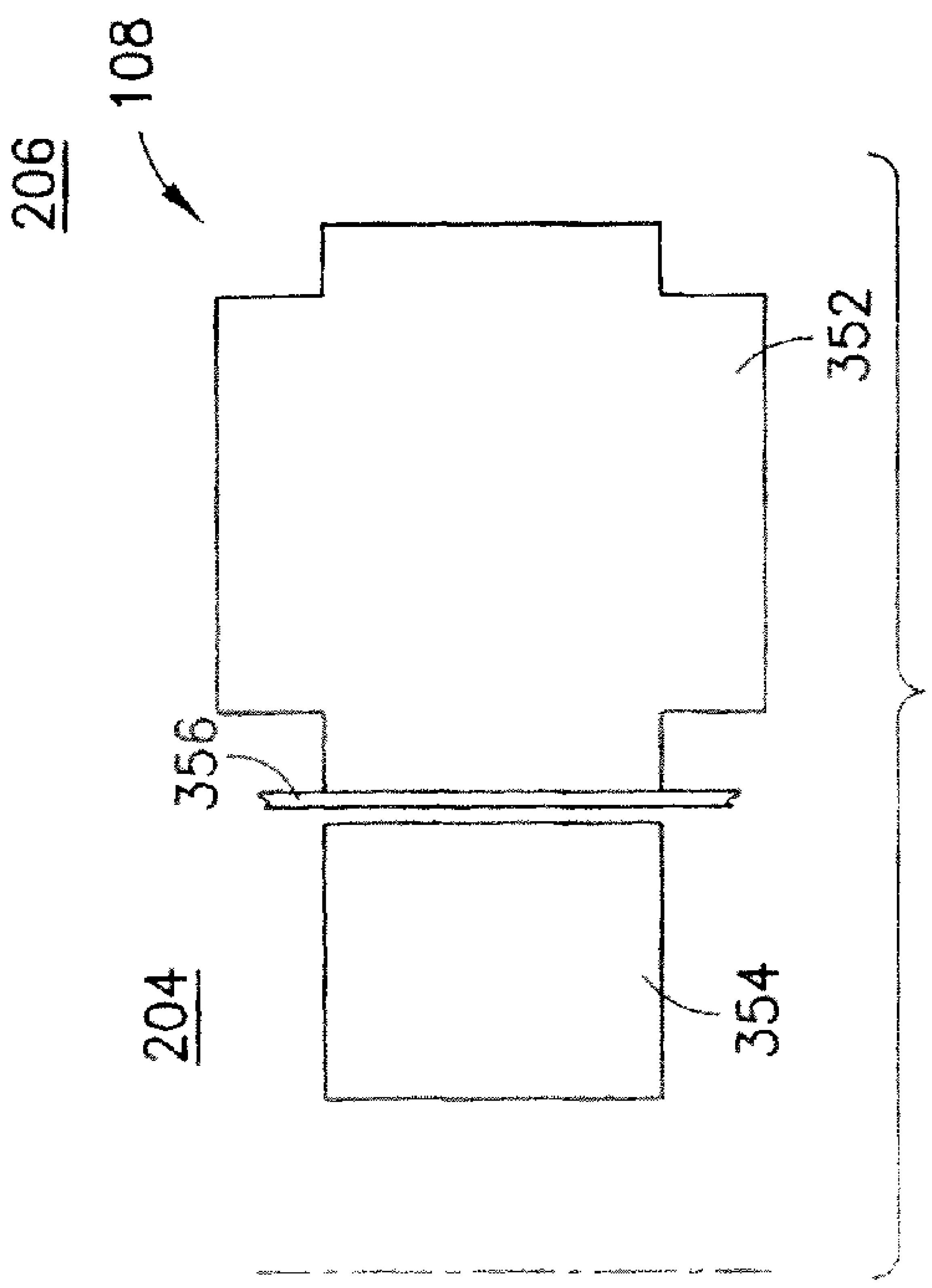

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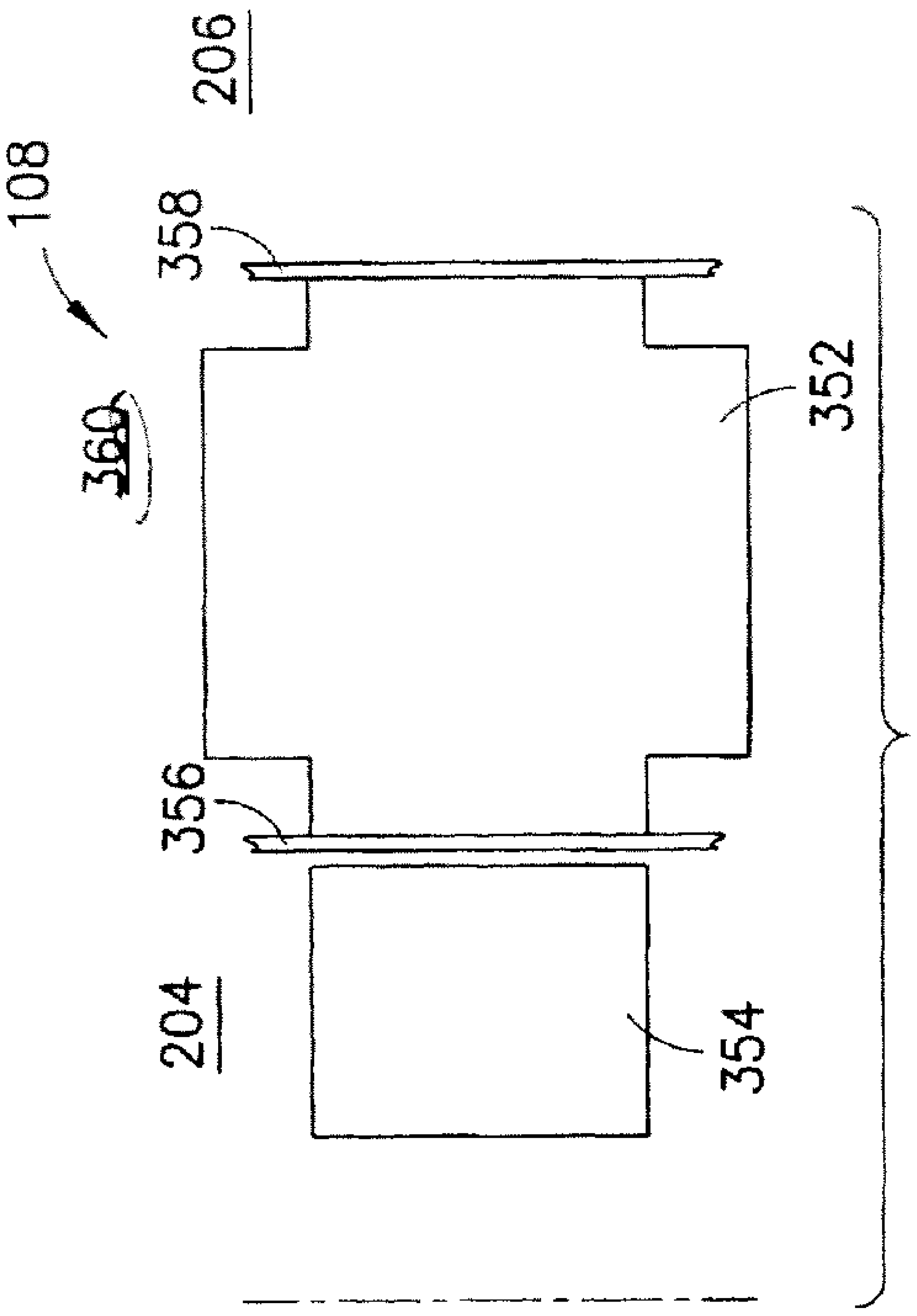

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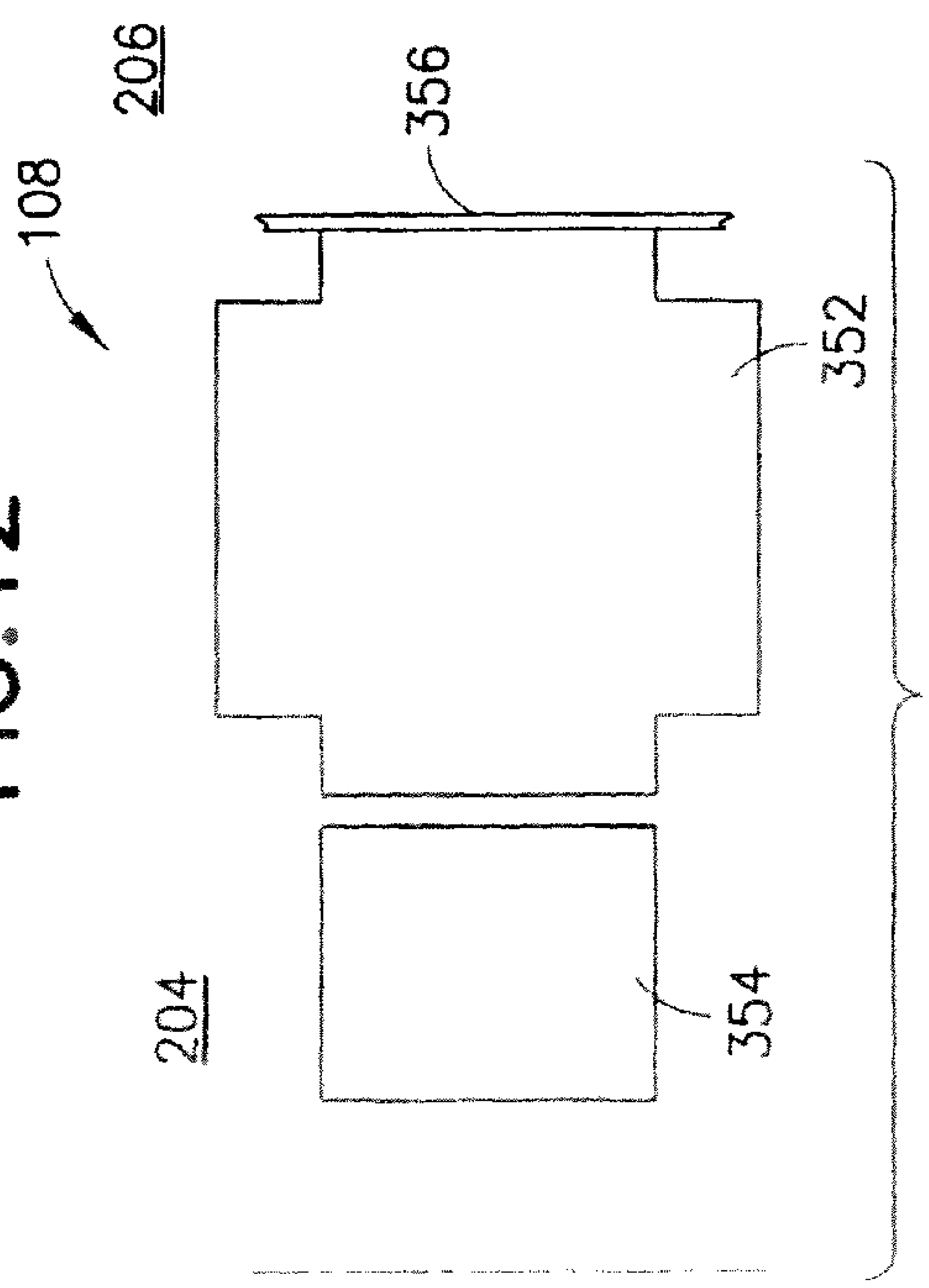


FIG. 14

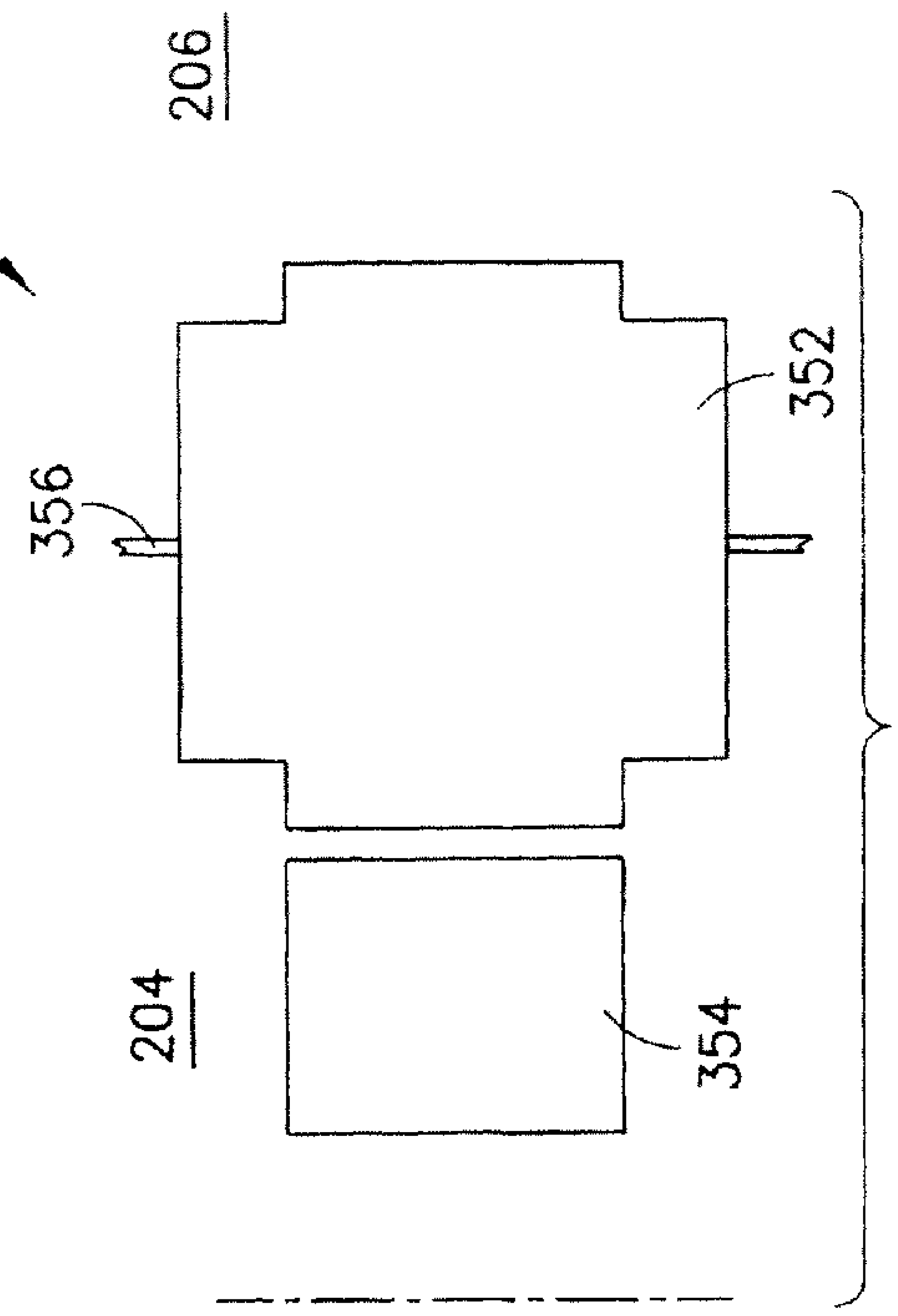


FIG. 15

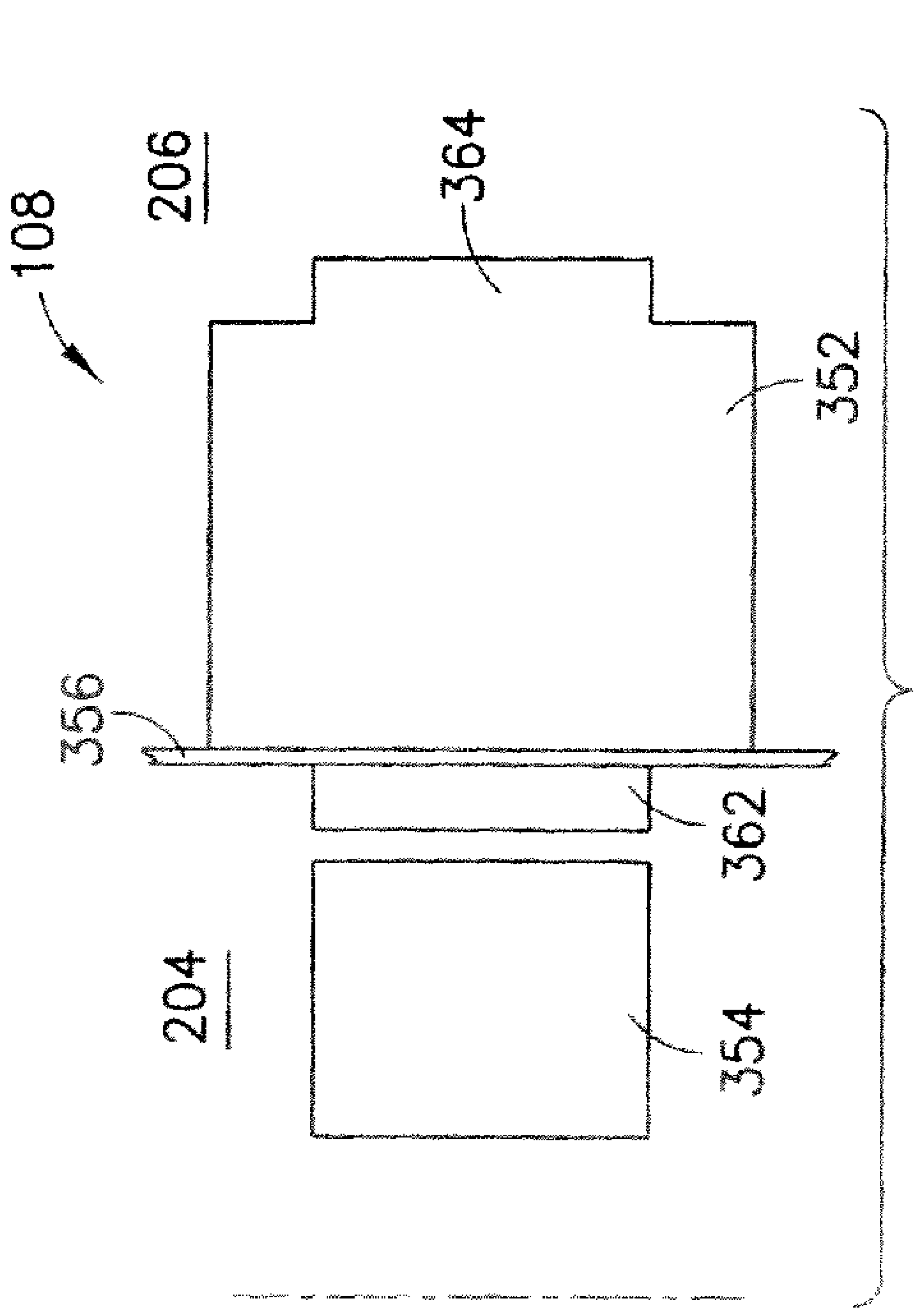


FIG.16

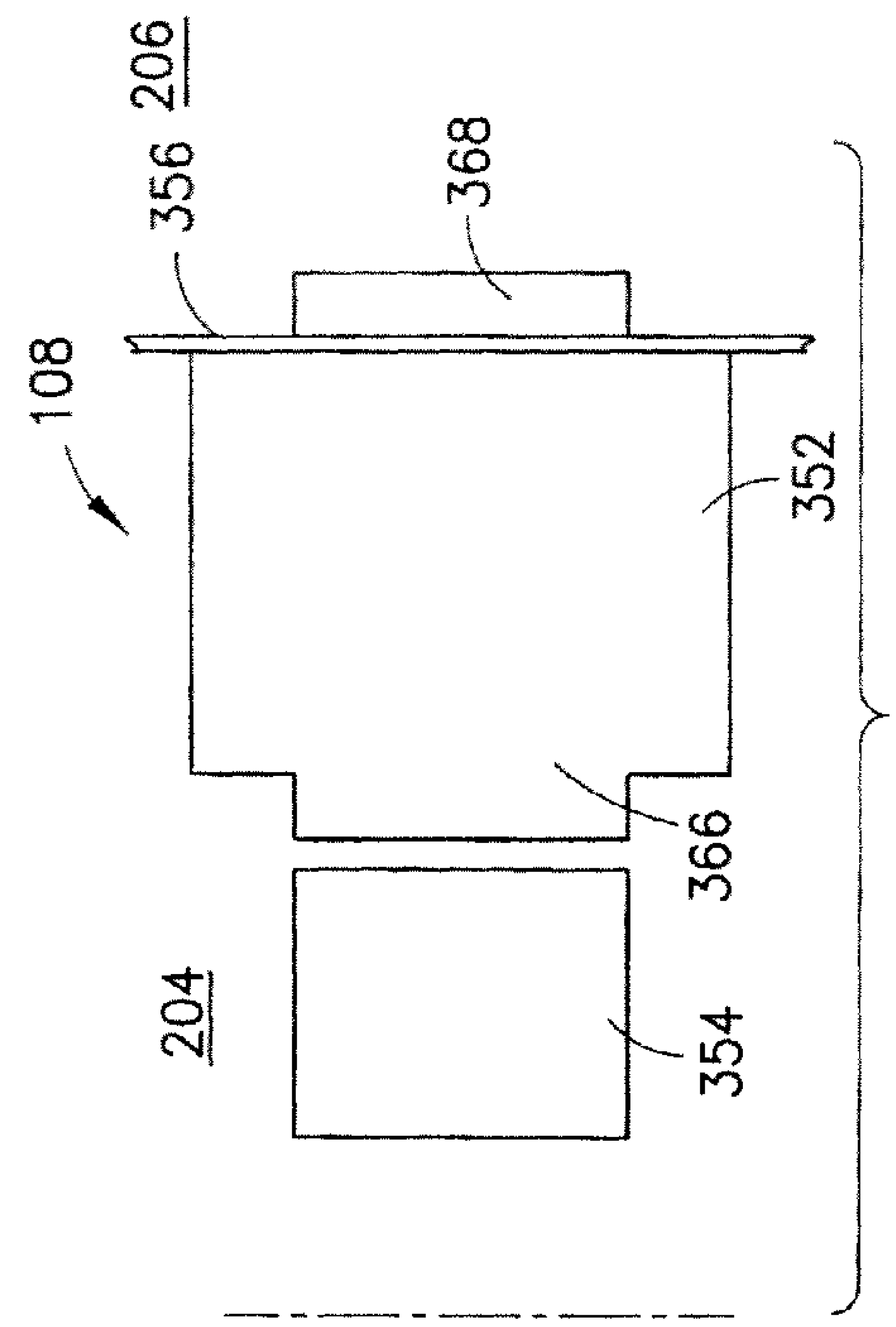
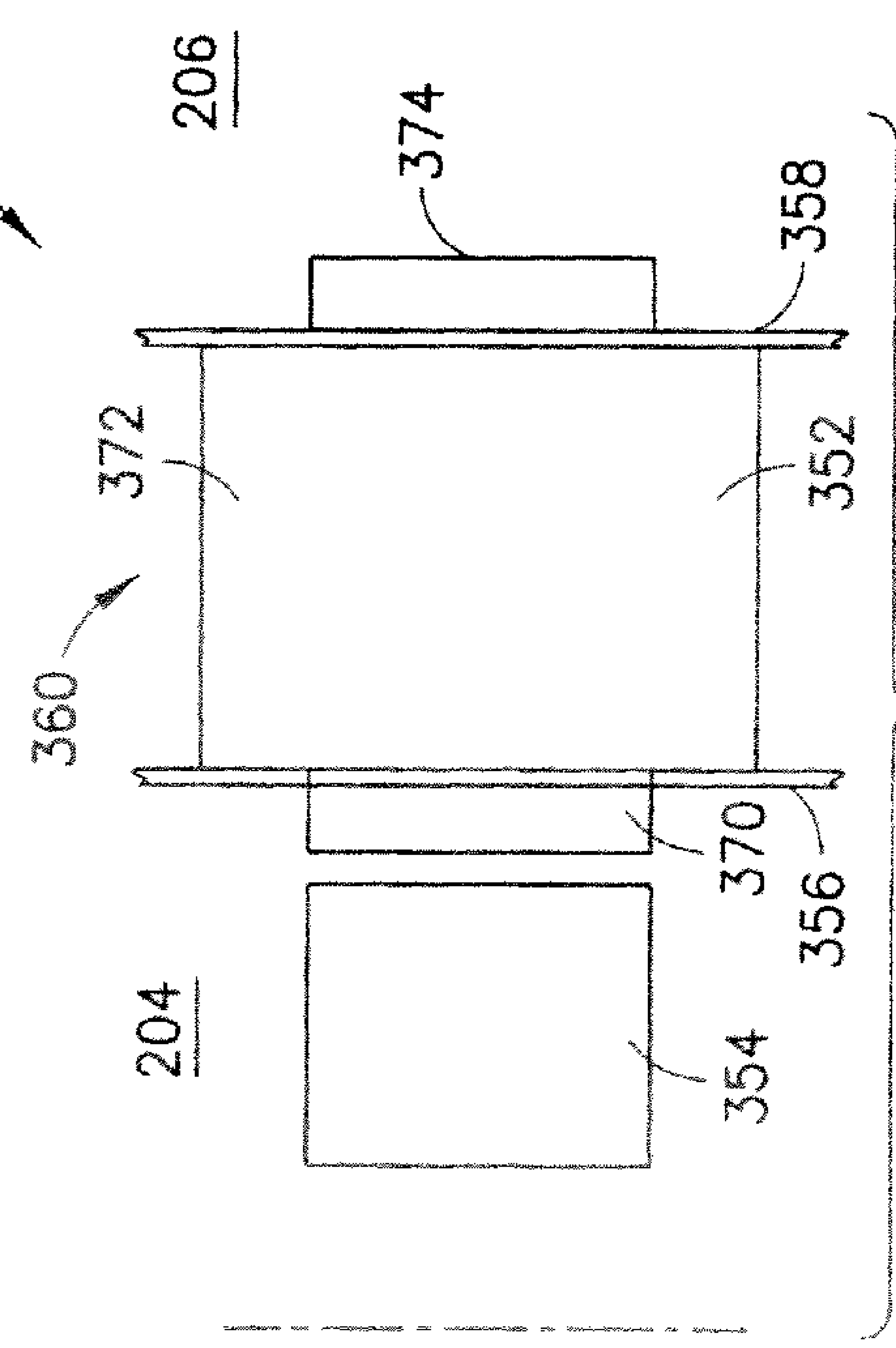


FIG.17



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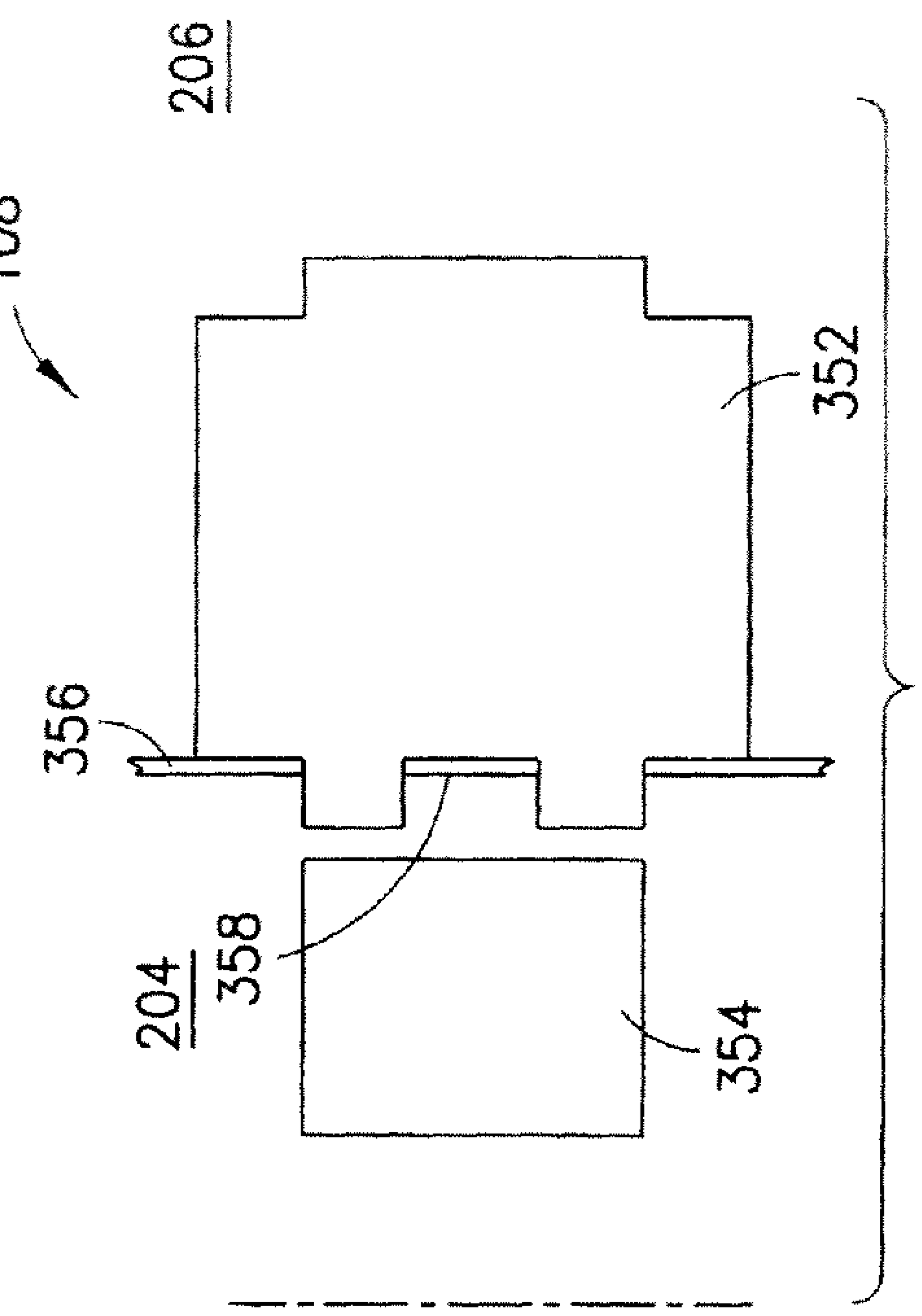

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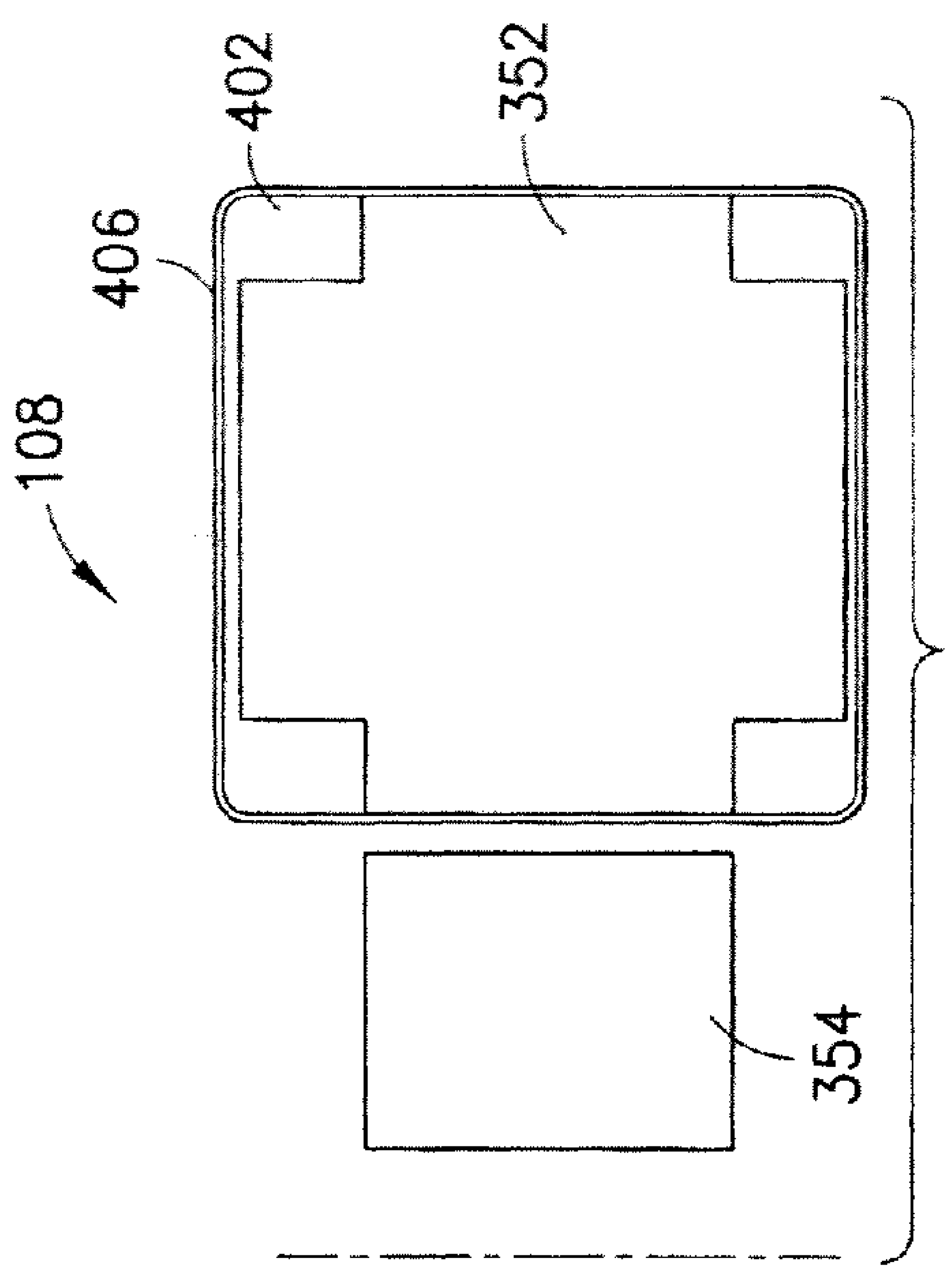

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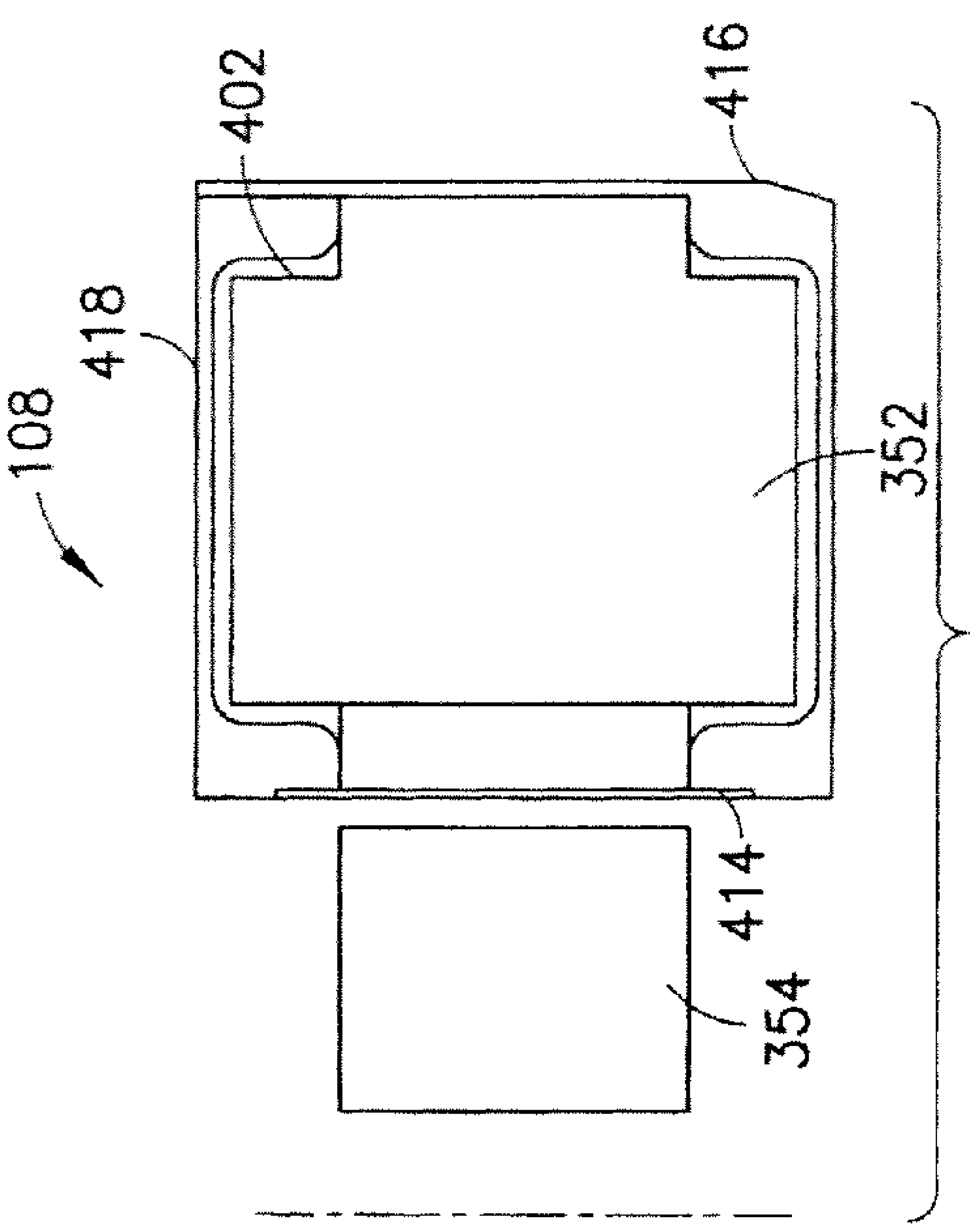

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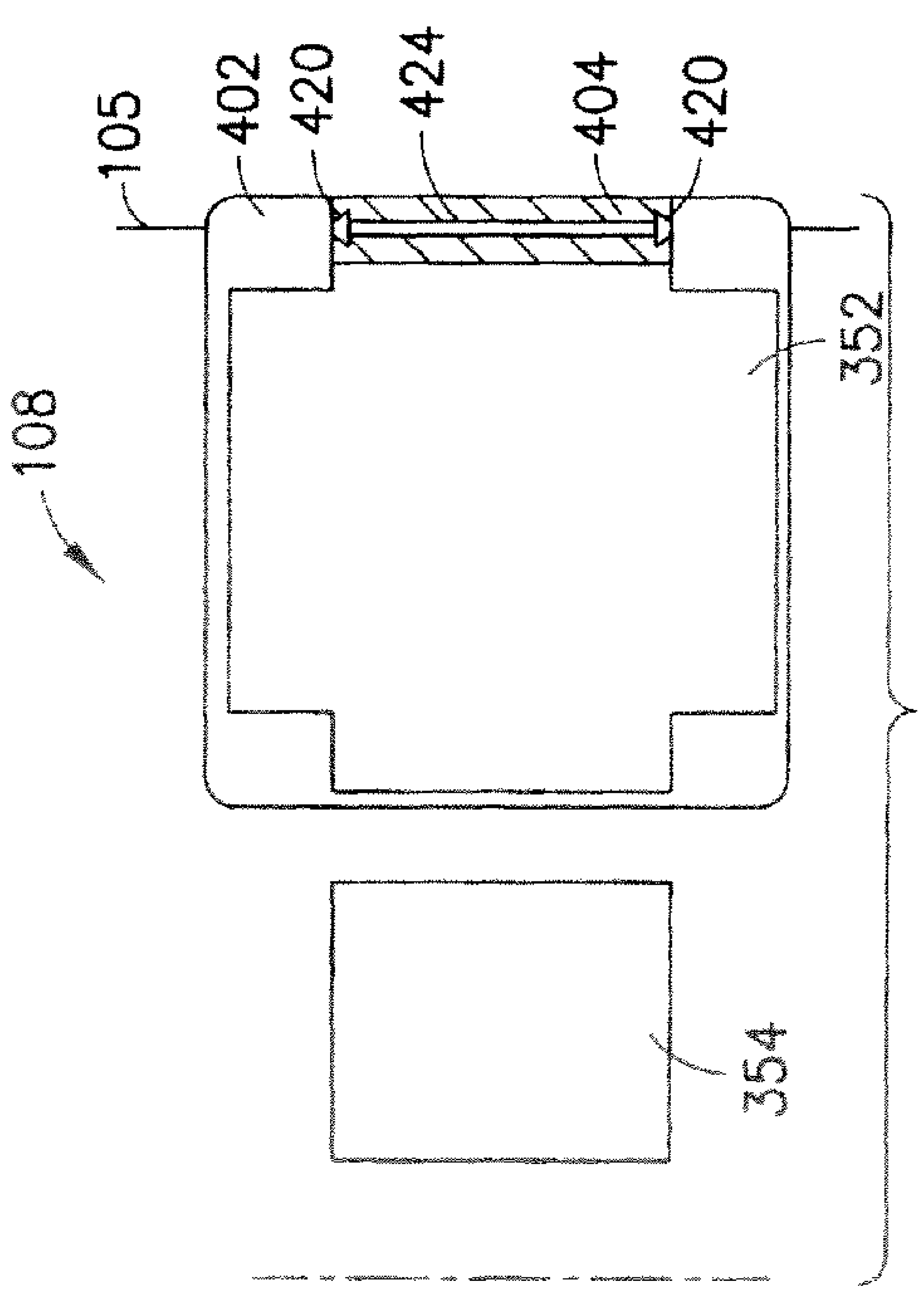
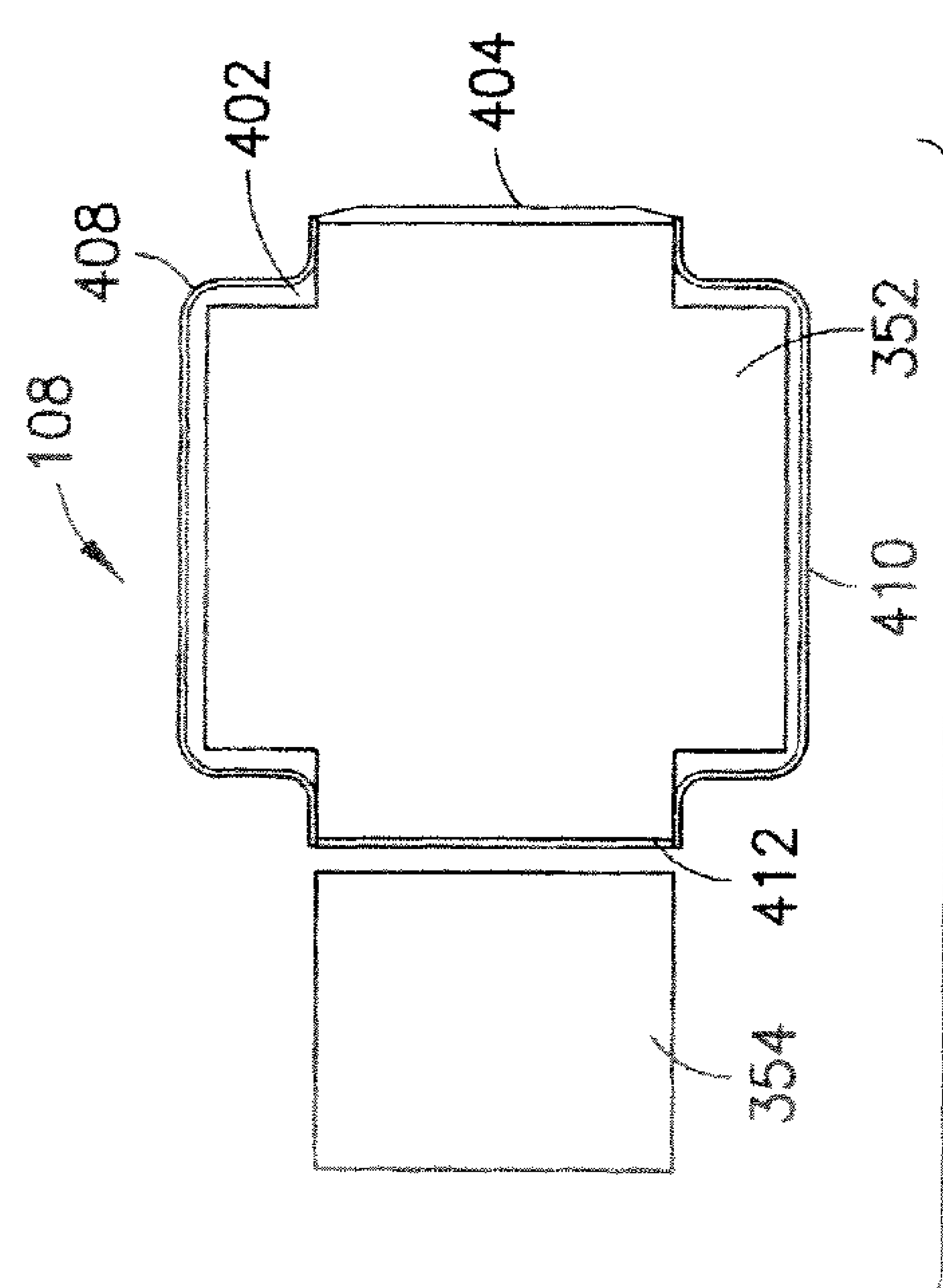


FIG.20



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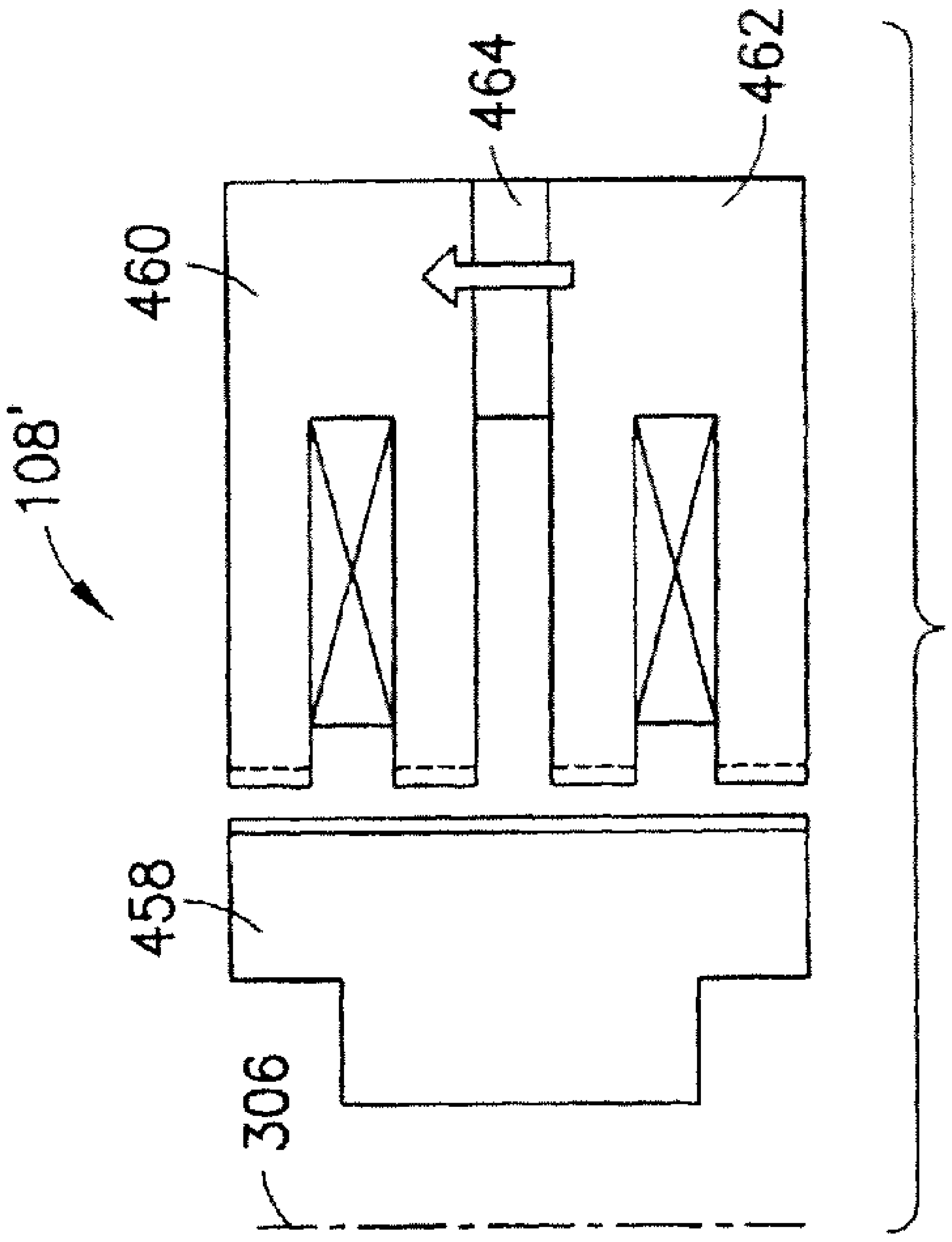

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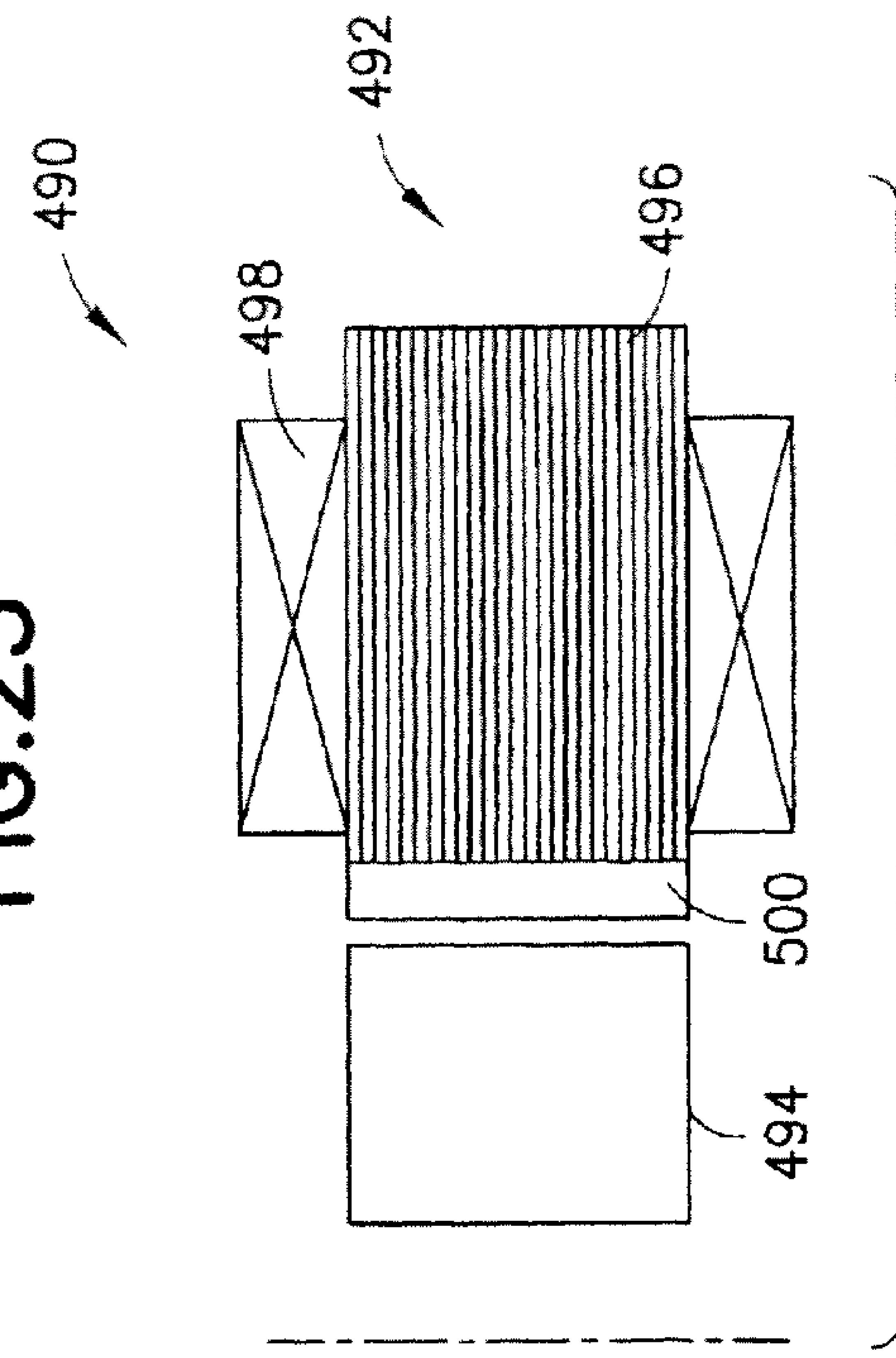

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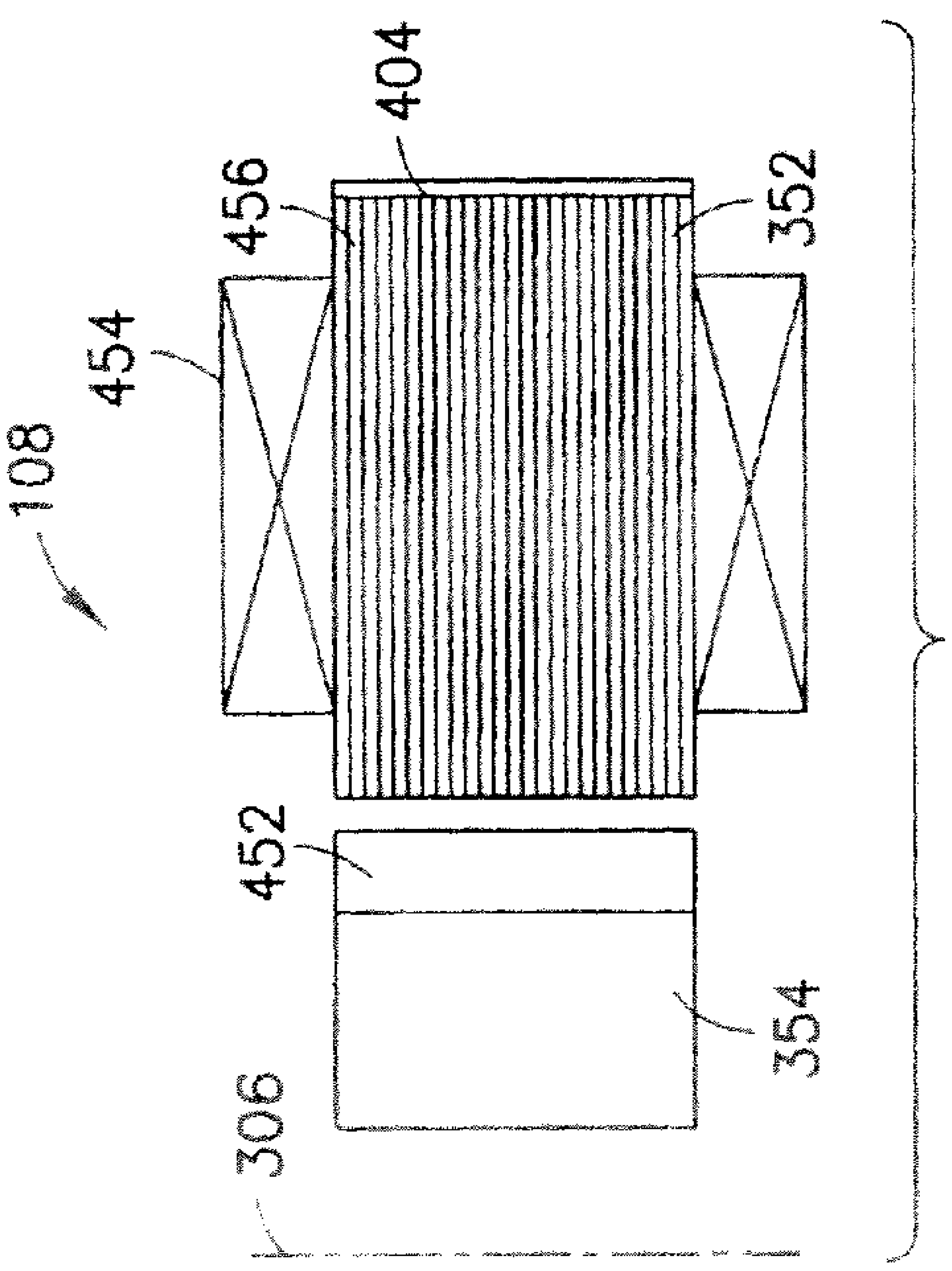

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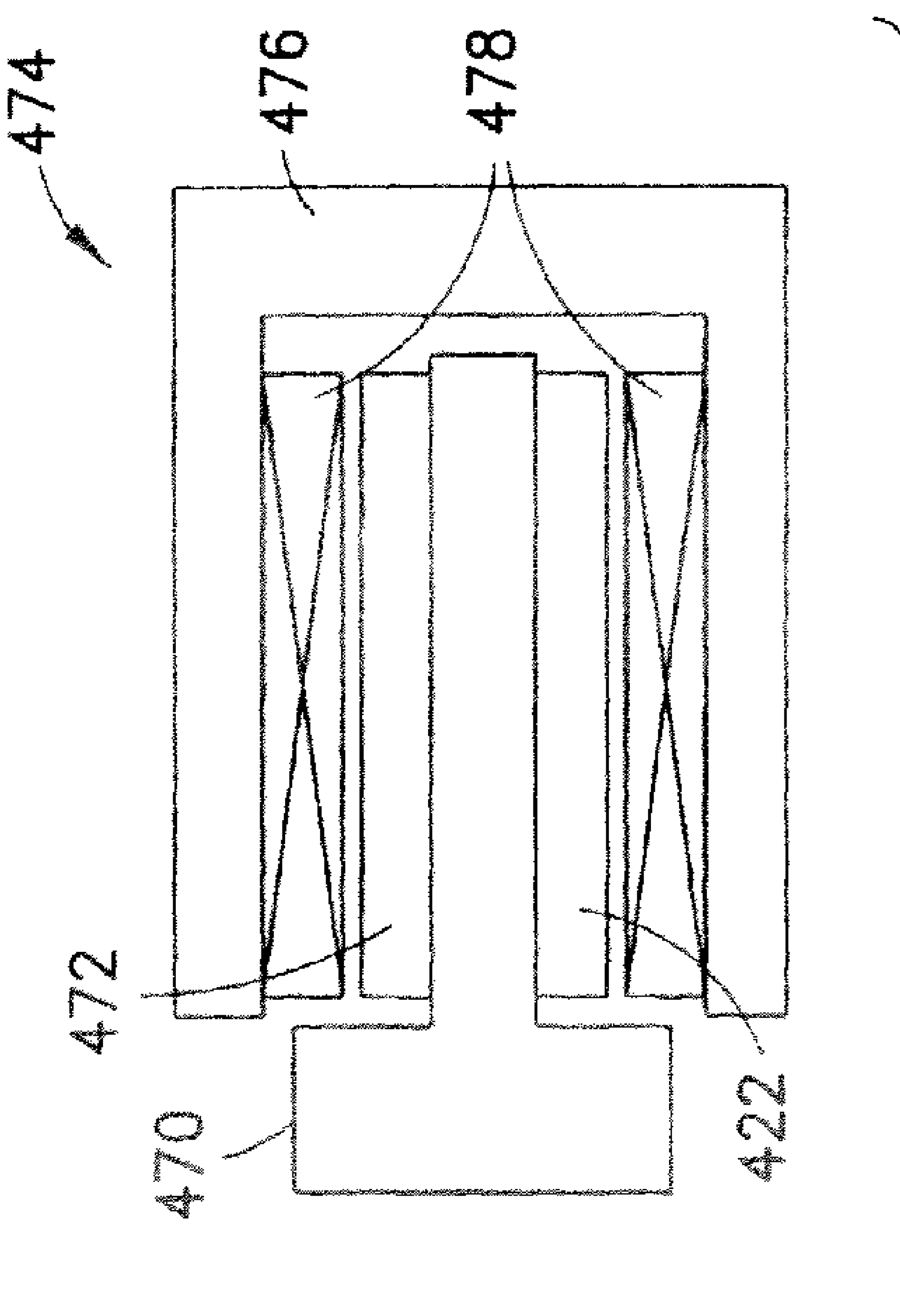

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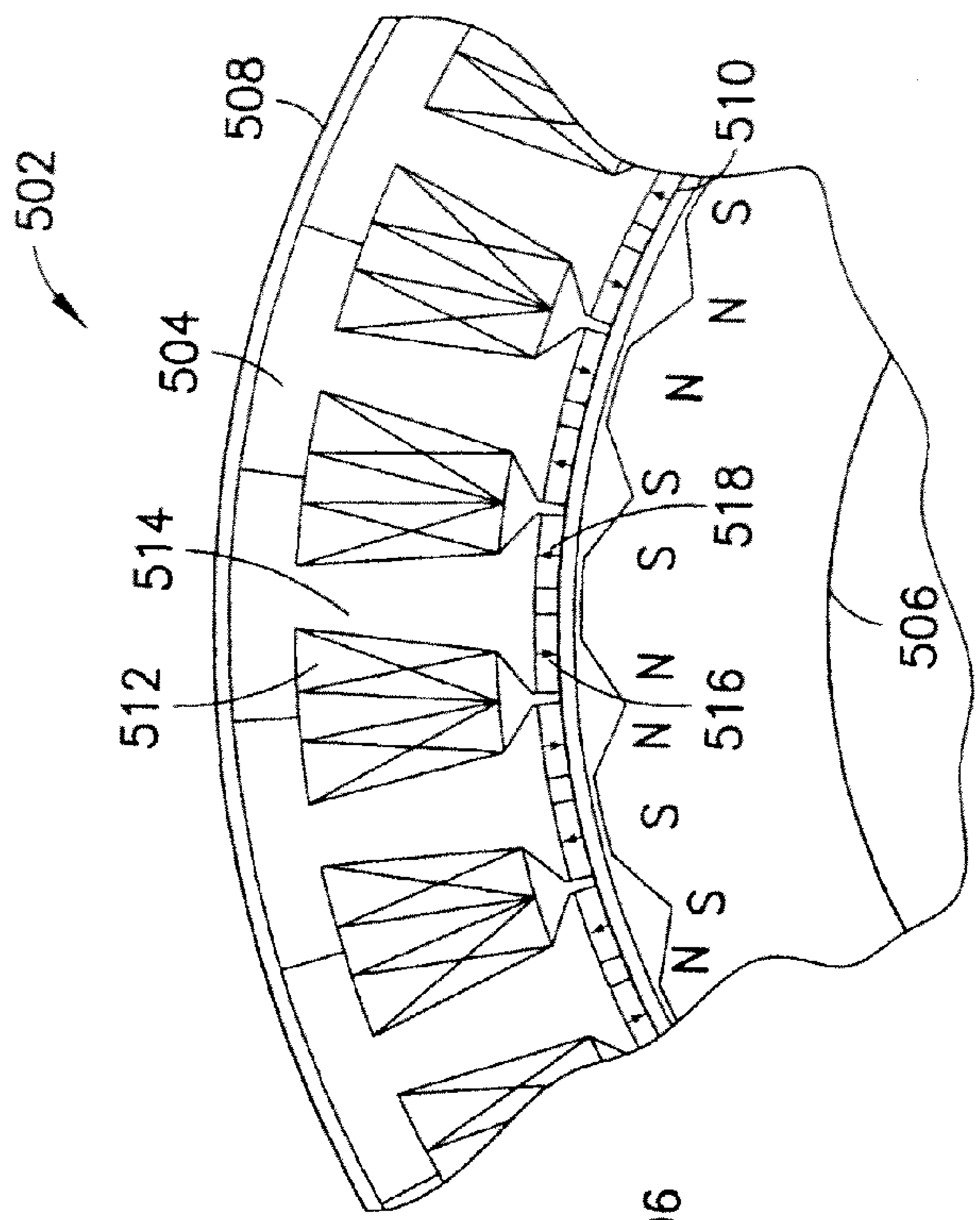

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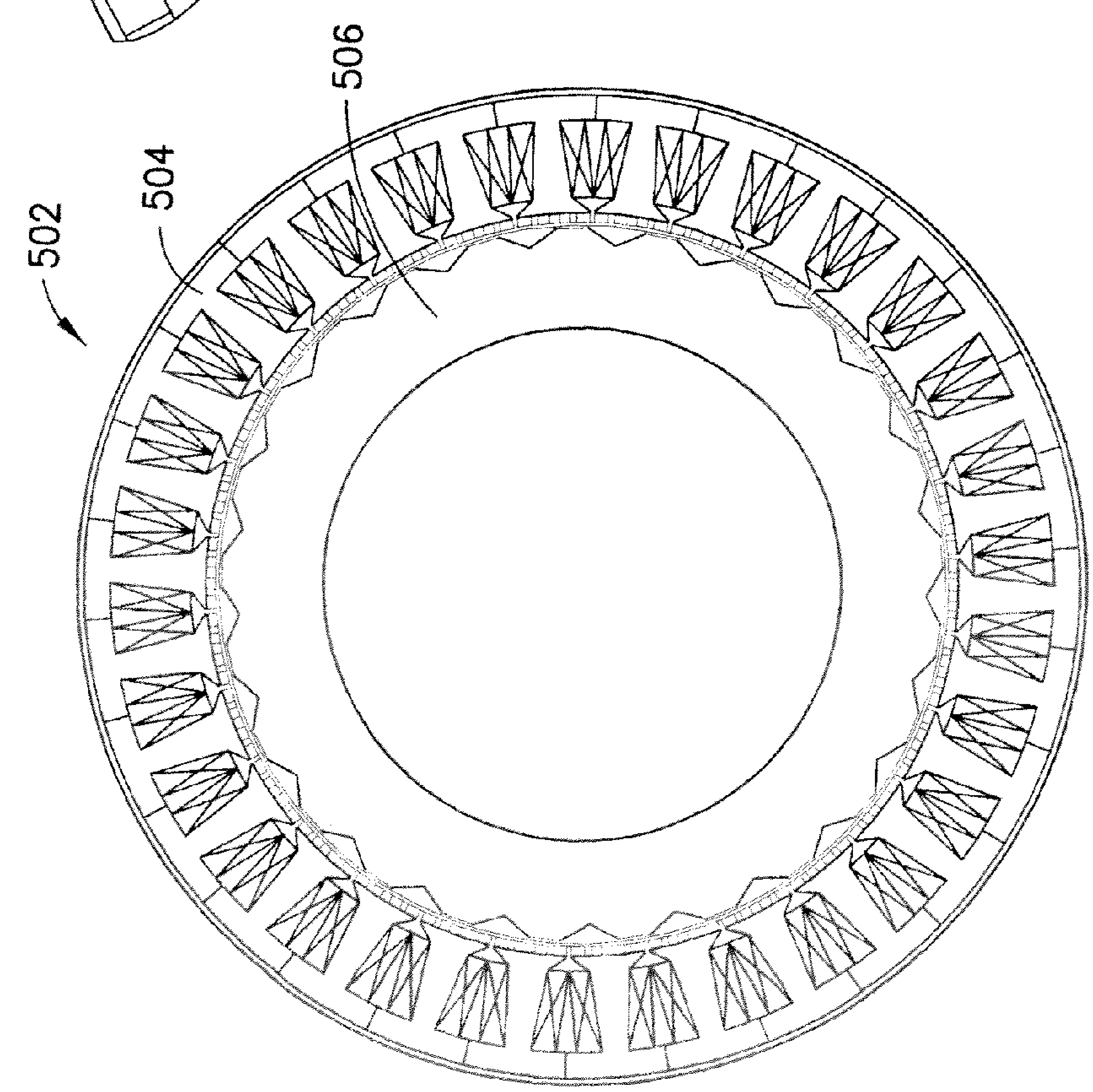

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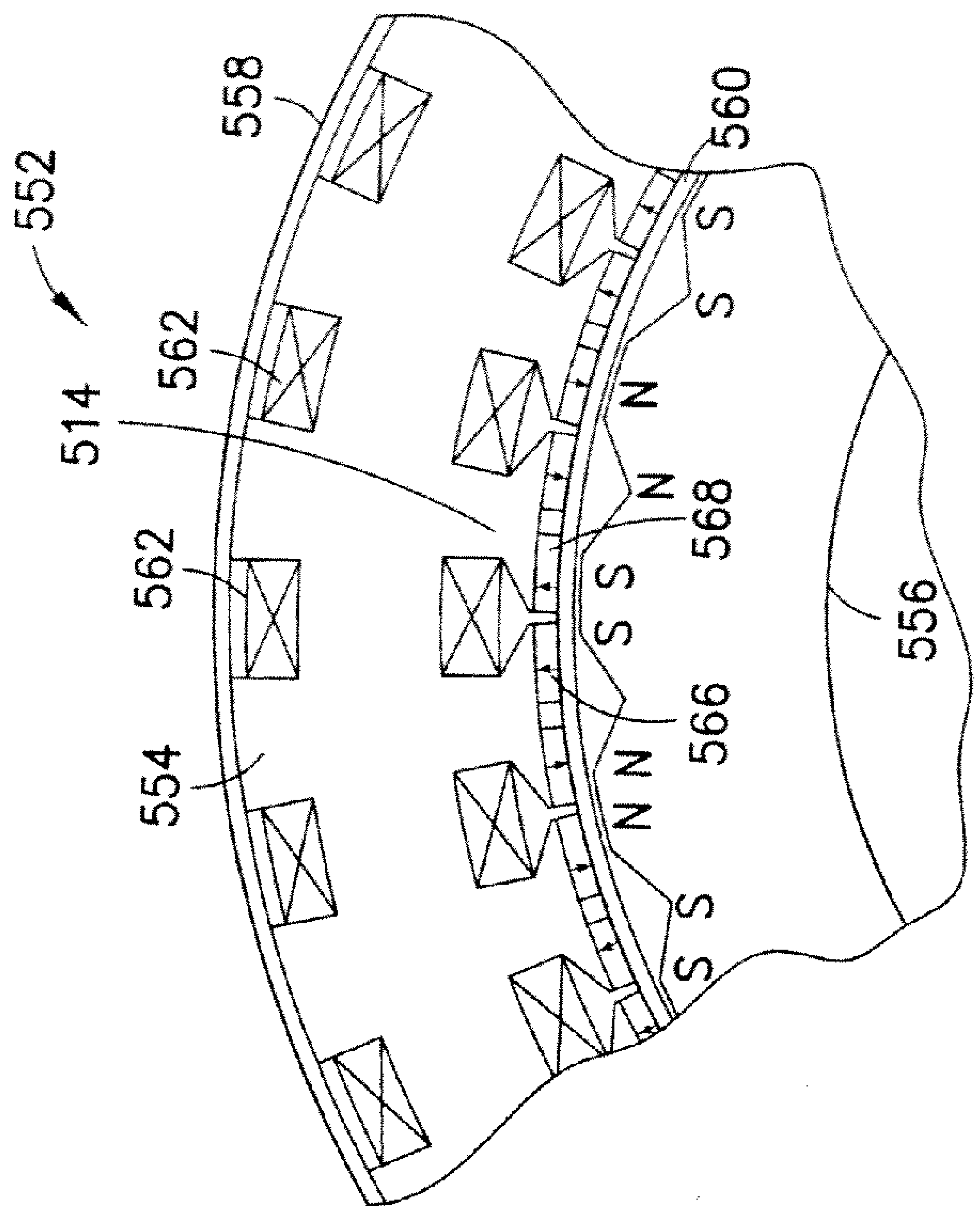

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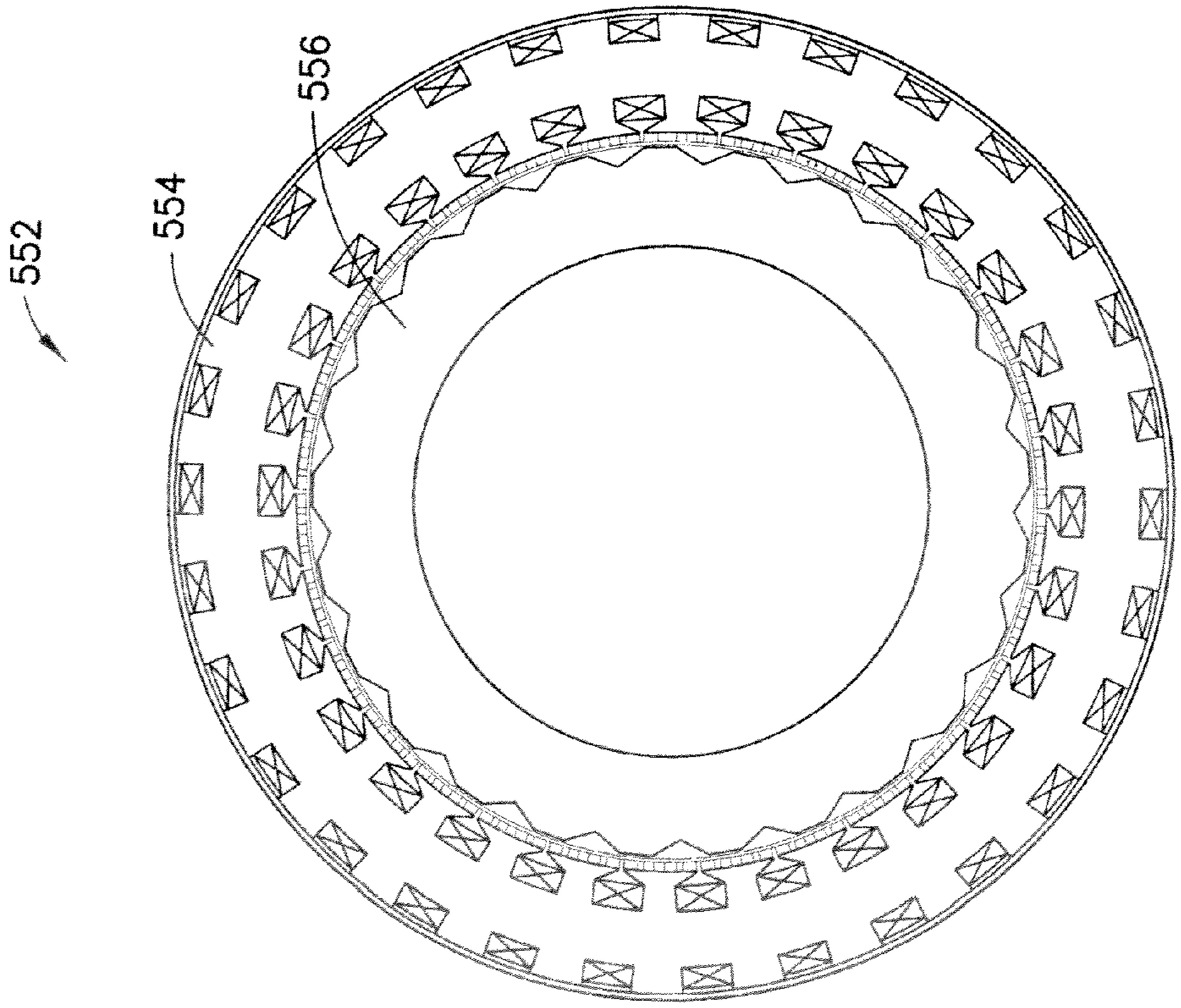

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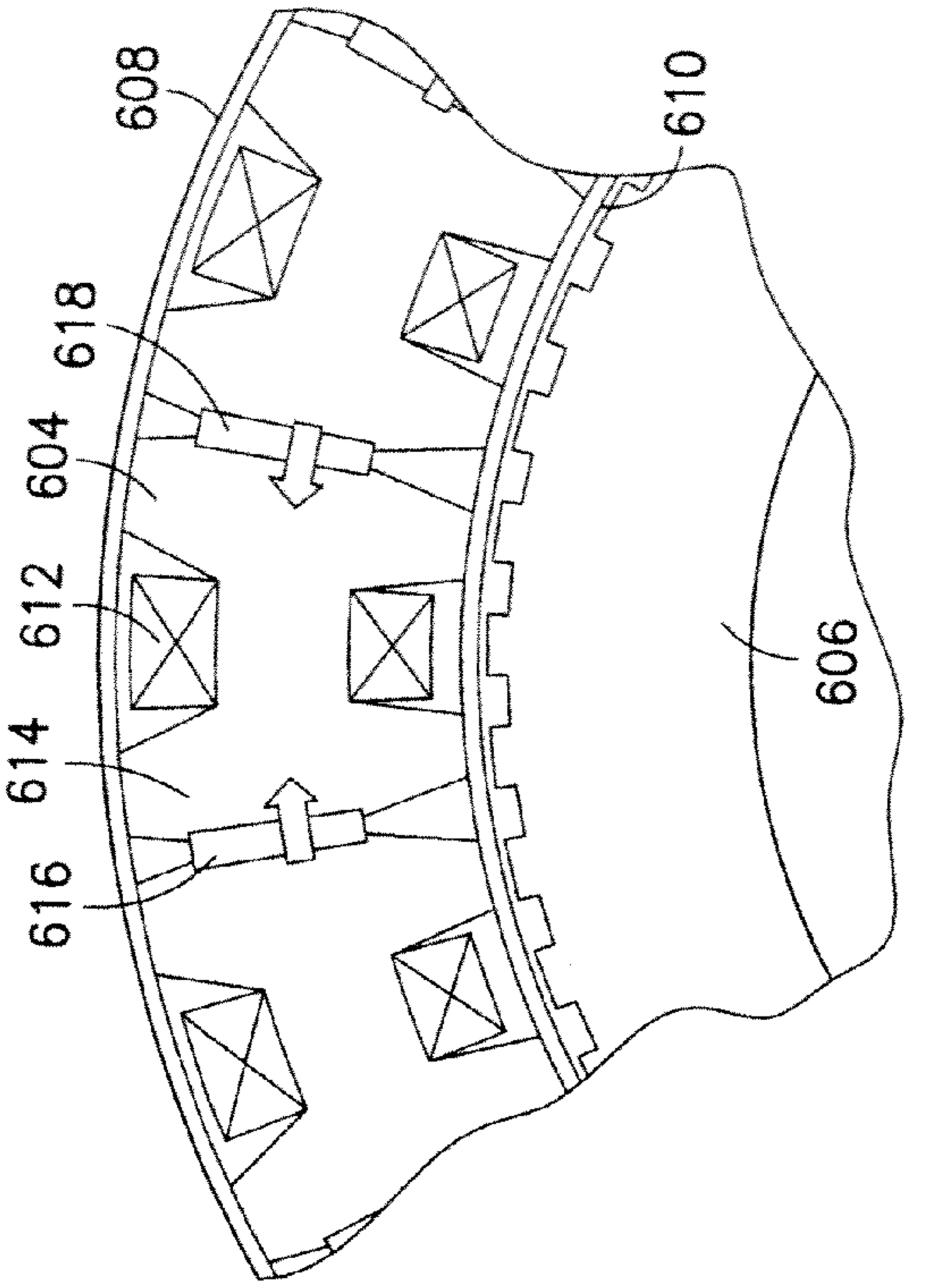

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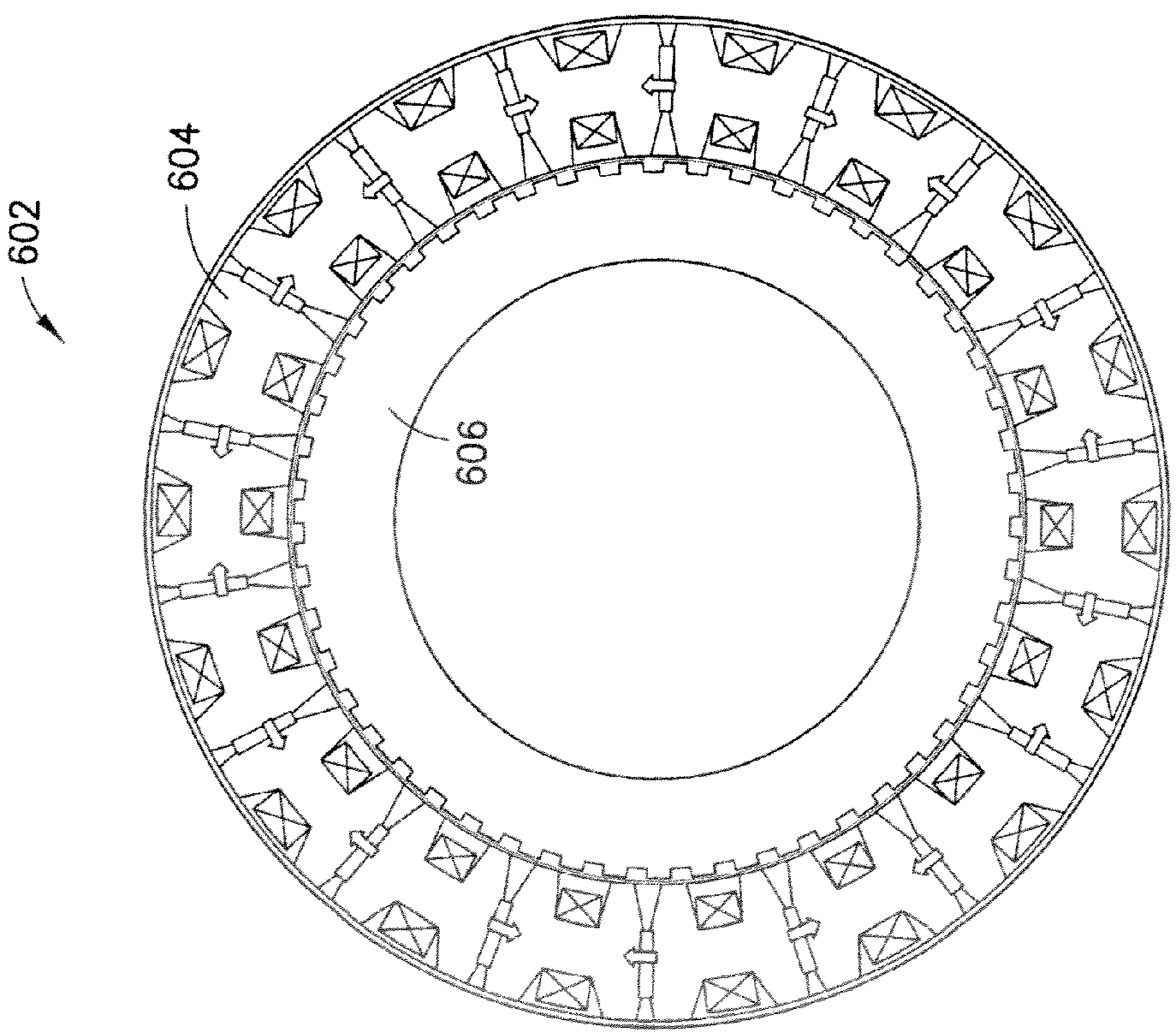

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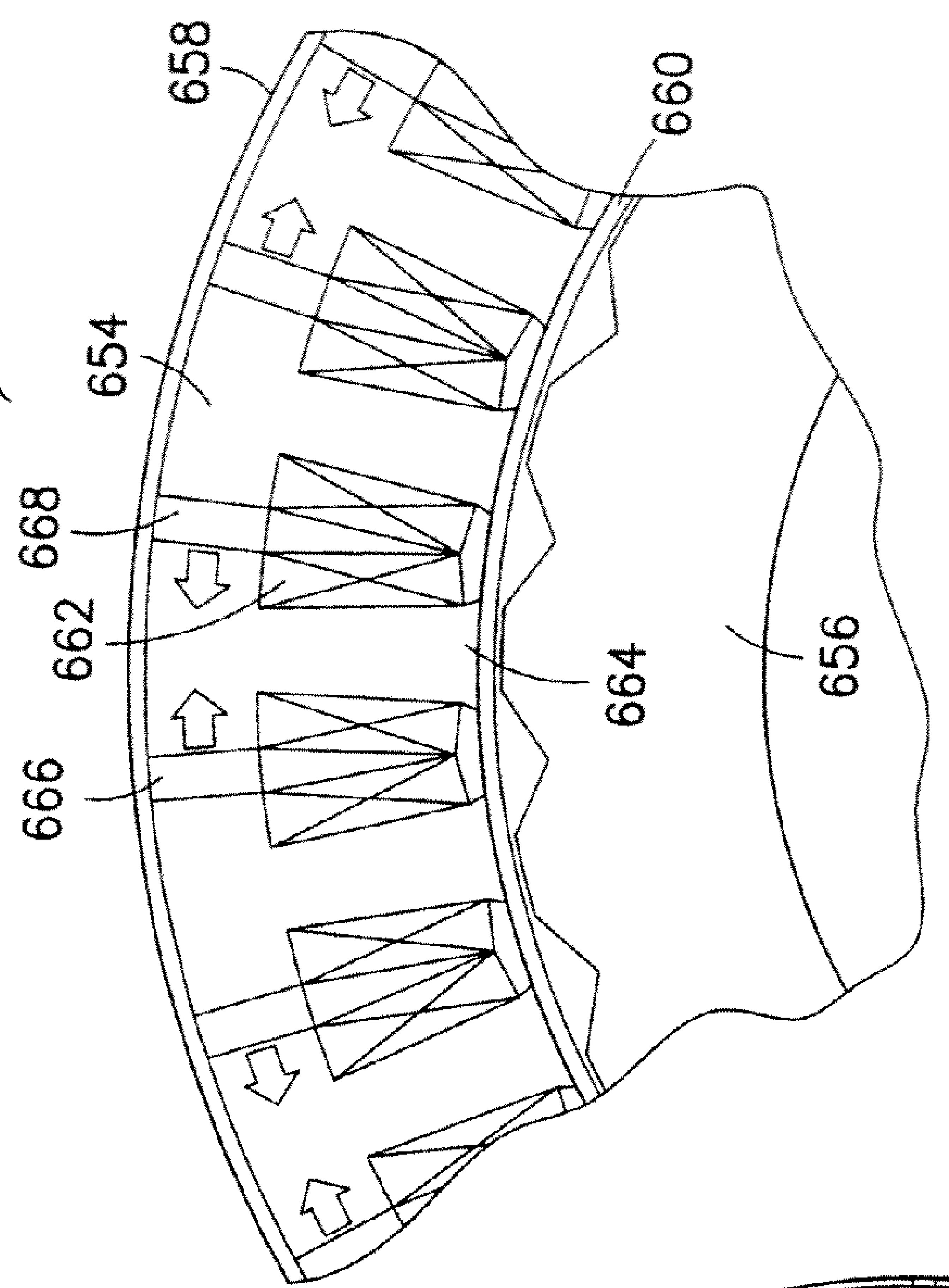

FIG.35

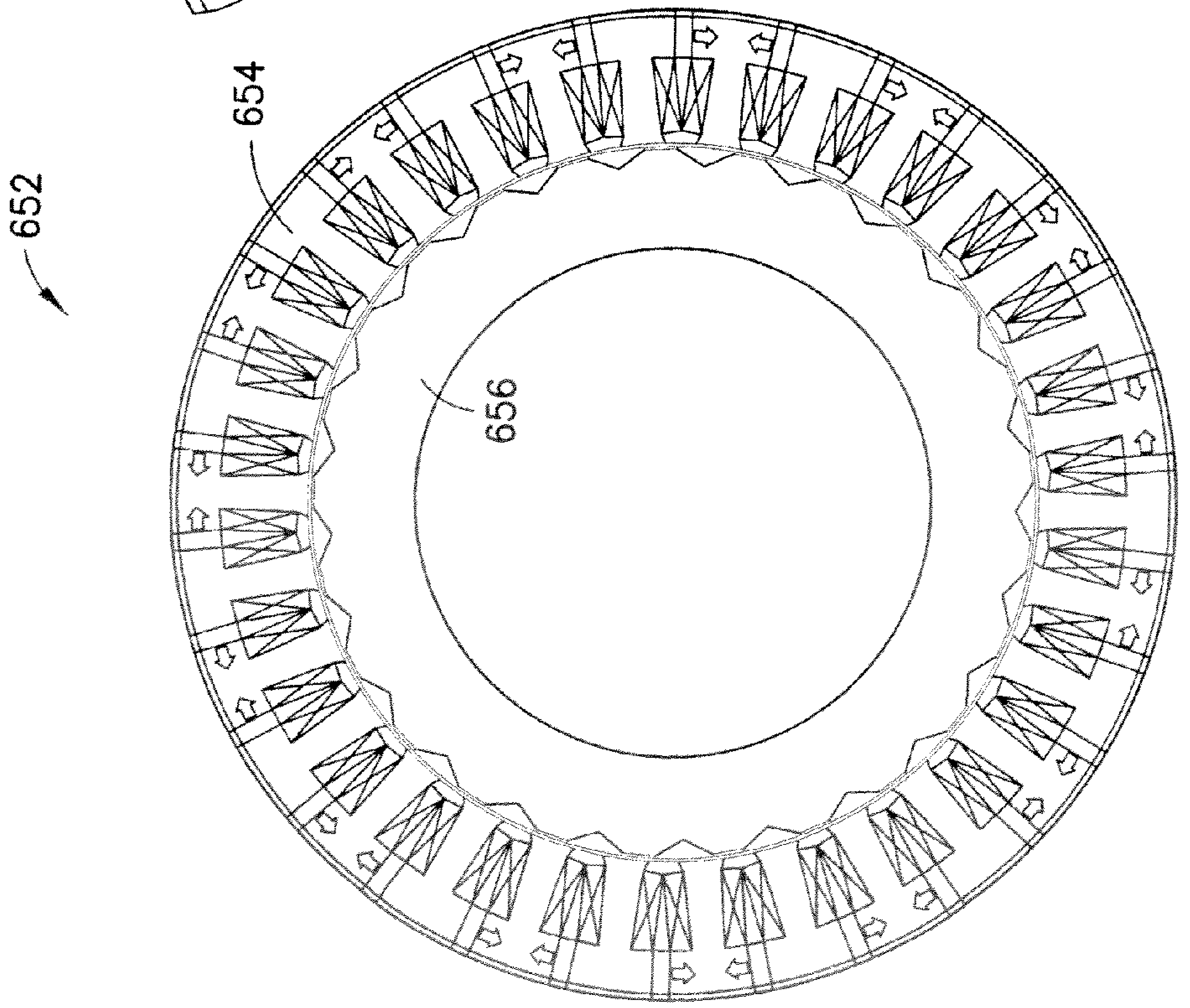

FIG.34

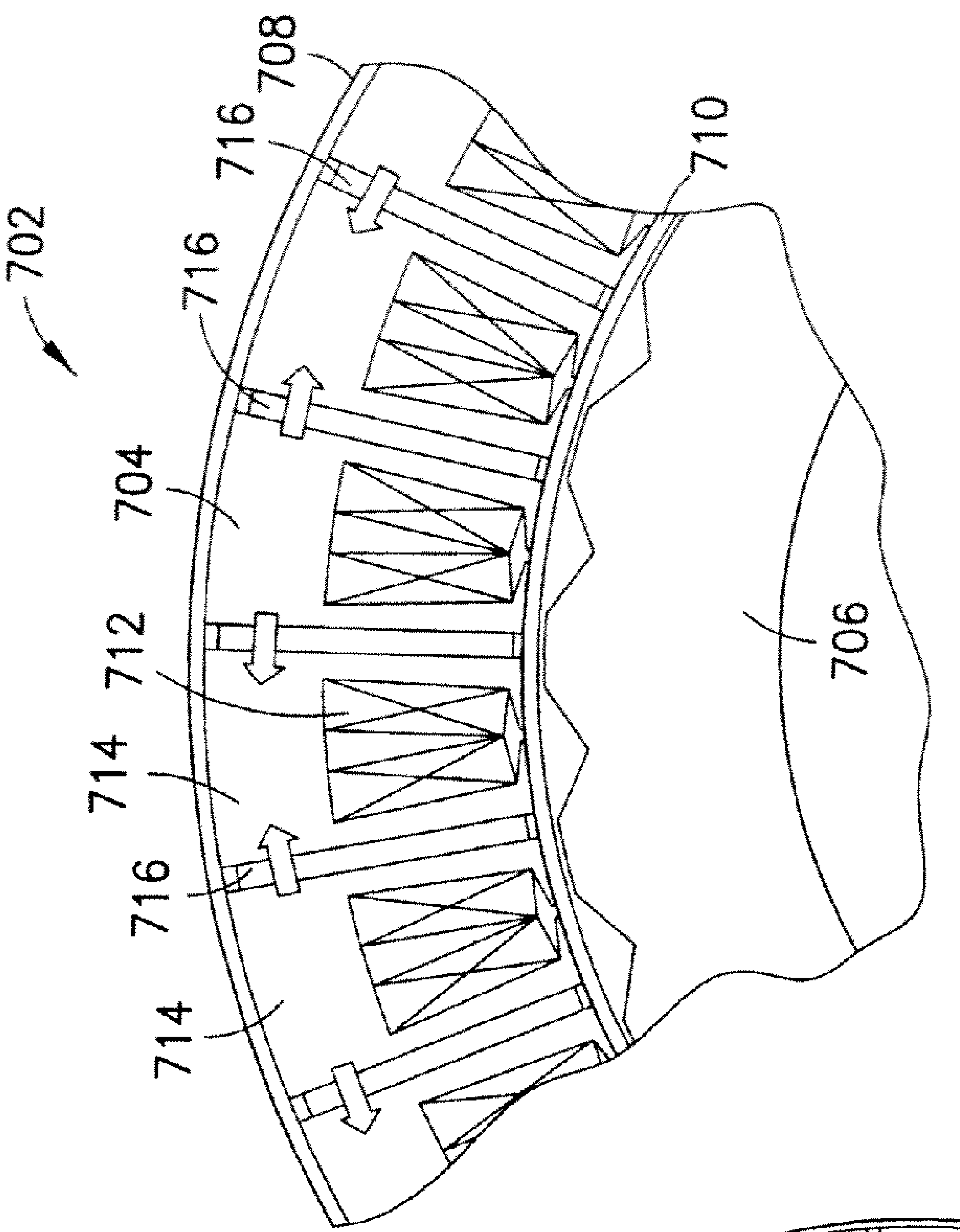

FIG.37

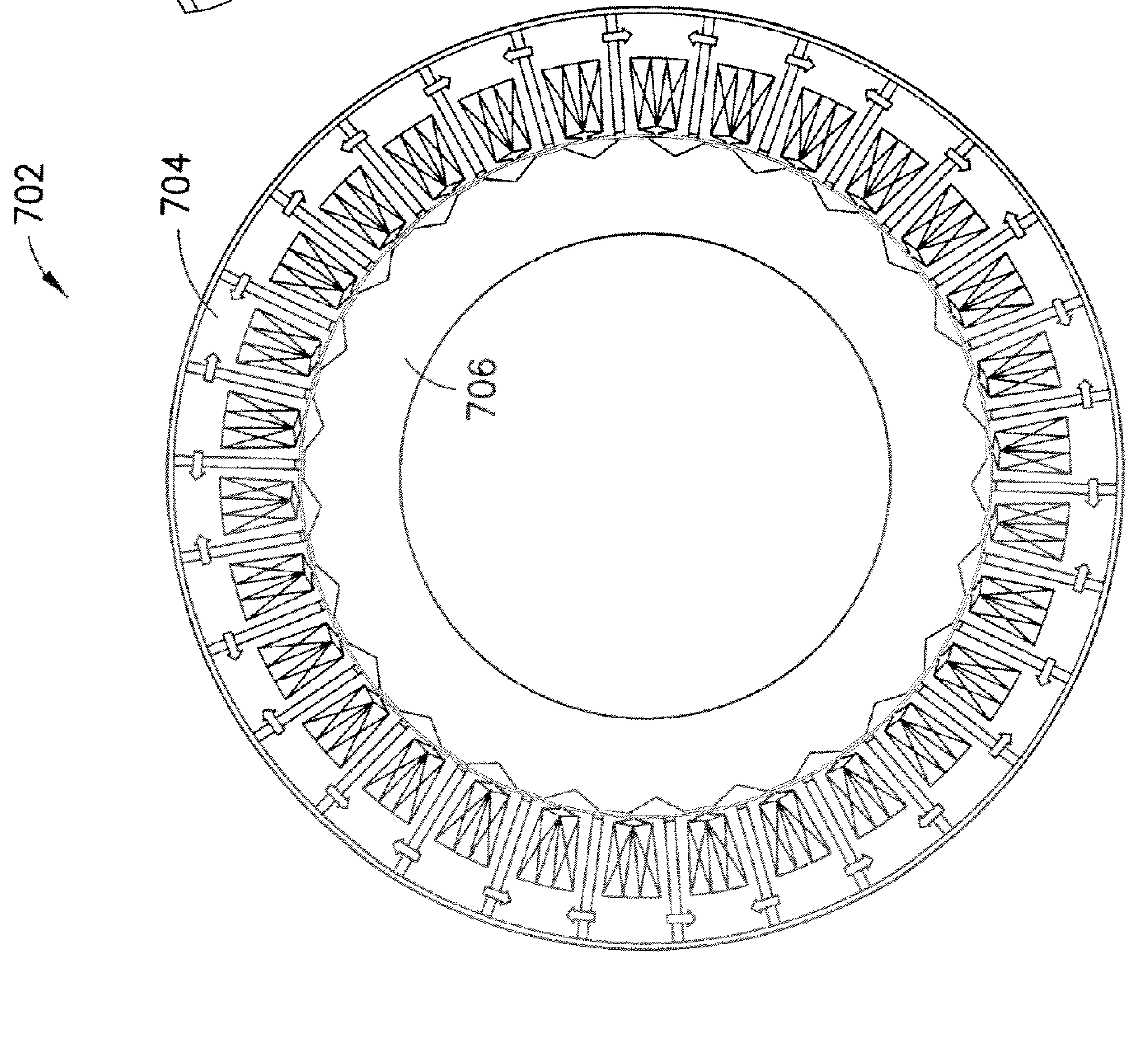

FIG.36

ROBOT DRIVE WITH RADIALLY ADJUSTABLE SENSOR CONNECTION

CROSS REFERENCE TO RELATED APPLICATIONS

This is a divisional patent application of copending U.S. application Ser. No. 13/618,315 filed Sep. 14, 2012, which claims priority under 35 USC 119(e) on Provisional Patent Application No. 61/627,030 filed Sep. 16, 2011 and Provisional Patent Application No. 61/683,297 filed Aug. 15, 2012, which are hereby incorporated by reference in their entireties.

BACKGROUND

Technical Field

The exemplary and non-limiting embodiments relate generally to a robot drive and, more particularly, to a drive having a passive rotor.

Brief Description of Prior Developments

Conventional manufacturing technologies for semiconductor integrated circuits and flat panel displays often include processing of silicon wafers and glass panels, often referred to as substrates, in fully automated cluster tools. A typical cluster tool may include a vacuum chamber with load locks and process modules. The tool is typically serviced by a robotic manipulator (robot or substrate transport apparatus) which cycles the substrates from the load locks, through the process modules, and back to the load locks. Another robot may be located in an atmospheric transfer module which serves as an interface between the load locks of the vacuum chamber and standardized load ports serviced by an external transportation system.

SUMMARY

The following summary is merely intended to be exemplary. The summary is not intended to limit the scope of the claims.

In accordance with one aspect, an example substrate transport apparatus is provided comprising a drive section comprising a first motor, where the first motor comprises a stator and a passive rotor; and a first movable arm assembly connected to the first motor. The substrate transport apparatus is configured for the first movable arm assembly to be positionable in a vacuum chamber with the passive rotor being in communication with an environment inside the vacuum chamber.

In accordance with another aspect, an example method comprises providing a substrate transport apparatus comprising a drive section and a first movable arm assembly connected to the drive section, where the drive section comprises a motor comprising a stator and a passive rotor; and connecting the substrate transport apparatus to a vacuum chamber, where the first movable arm assembly is positioned in the vacuum chamber with the passive rotor being in communication with an environment inside the vacuum chamber.

In accordance with another aspect, an example substrate transport apparatus comprises a drive section comprising a first motor, where the first motor comprises a stator and a passive rotor; a first movable arm assembly connected to the first motor; and a gas barrier located in a gap between the stator and the passive rotor to separate an environment at the passive rotor from an environment at the stator.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing aspects and other features are explained in the following description, taken in connection with the accompanying drawings, wherein:

FIG. **1** is a schematic sectional view of an example apparatus;

FIG. **2** is a schematic view of a feed-through;

FIG. **3**A is a schematic view of another feed-through;

FIG. **3**B is a schematic view of another feed-through;

FIG. **3**C is a schematic view of another feed-through;

FIG. **3**D is a schematic view of another feed-through;

FIG. **4** is a schematic view of a read-head connected to a housing;

FIG. **5** is a schematic view of another example of the read-head connected to the housing;

FIG. **6** is a schematic view of another example of the read-head connected to the housing;

FIG. **7** is a schematic view of another example of the read-head connected to the housing;

FIGS. **8** and **9** are schematic views of another example of the read-head connected to the housing;

FIGS. **10** and **11** are schematic views of another example of the read-head connected to the housing;

FIGS. **12-19** are schematic view of various separation wall configurations;

FIGS. **20-23** are schematic views of various stator and rotor combinations with stator encapsulation;

FIG. **24** illustrates a motor having a radial field arrangement;

FIG. **25** illustrates a hybrid motor design having a toothed passive rotor, a stator phase A and stator phase B separated by ring permanent magnet;

FIG. **26** illustrates a motor having an axial field design;

FIG. **27** illustrates a motor having a brushless design with a passive rotor;

FIGS. **28-29** illustrate a motor with a toothed passive rotor;

FIGS. **30-31** illustrate a motor with a toothed passive rotor;

FIGS. **32-33** illustrate a motor with a toothed passive rotor;

FIGS. **34-35** illustrate a motor with a toothed passive rotor; and

FIGS. **36-37** illustrate a motor with a toothed passive rotor.

DETAILED DESCRIPTION OF EMBODIMENTS

Referring to FIG. **1**, there is shown a schematic view of a robot drive **10** of a substrate transport apparatus **2**. Although the robot drive **10** is described with respect to a vacuum robot, any suitable robot drive (atmospheric or otherwise) may be provided having features as disclosed. Drive **10** may incorporate features as previously disclosed or as disclosed herein. Aside from the preferred embodiment or embodiments disclosed, this invention is capable of other embodiments and of being practiced or being carried out in various ways. Thus, it is to be understood that the invention is not limited in its application to the details of construction and the arrangements of components set forth in the following description or illustrated in the drawings. If only one embodiment is described herein, the claims hereof are not to be limited to that embodiment. Moreover, the claims hereof are not to be read restrictively unless there is clear and convincing evidence manifesting a certain exclusion, restriction, or disclaimer.

An example robotic manipulator or apparatus **2** incorporating the vacuum-compatible direct-drive system of one or more embodiments of this invention is shown in FIG. **1**. The robotic manipulator may be built around frame **101**, e.g., an aluminum extrusion, suspended from flange or mounting arrangement **102**. Alternatively, the mounting arrangement may be on the side of frame **101**, at the bottom of frame **101** or frame **101** may be mounted in any other suitable manner. Frame **101** may incorporate one or more vertical rail **103** with linear bearings **104** to provide guidance to housing **105** driven by motor **106** via ball-screw mechanism **107**. Only one rail **103** is shown for simplicity. Alternatively, motor housing **105** may be driven by a linear motor, attached directly to frame **101** or coupled to frame **101** in any other suitable movable or immovable manner. Motor housing **105** may incorporate one, two, three, four or more direct-drive modules as will be described in greater detail below. Housing **105** may house motors **108**, **109** equipped with position encoders **110** and **111**. Housing **105** is shown as an exemplary structure where housing **105** may have portions configured with respect to motors **108**, **109** and position encoders **110** and **111** as will be described in greater detail below. Bellows **120** may be used to accommodate motion of motors **105** along vertical rail(s) **103**, separating the environment where movable components of motors **108**, **109** and encoders **110**, **111** operate, for instance vacuum, from the outside environment, for example, atmosphere.

In the example of FIG. **1**, two direct-drive modules, each having one motor and one encoder, are shown. However, any suitable number of direct-drive modules with any suitable number of motors and encoders may be used. Inverted service loop **222** may be utilized to supply power to the direct-drive module(s) and facilitate signaling between the direct-drive module(s) and other components of the robotic system, such as a controller **224**, as shown in FIG. **1**. Alternatively, a regular, non-inverted service loop **226** may be employed. As shown in FIG. **1**, upper motor **108** may drive hollow outer shaft **112** connected to first link **114** of the robot arm. Lower motor **109** may be connected to coaxial inner shaft **113** which may be coupled via belt drive **115** to second link **116**. Another belt arrangement **117** may be employed to maintain radial orientation of third link **118** regardless of the position of the first two links **114** and **116**. This may be achieved due to a 1:2 ratio between the pulley incorporated into the first link and the pulley connected to the third link. Third link **118** may form an end-effector that may carry payload **119**, for instance, a semiconductor substrate. It should be noted that the robotic arm of FIG. **1** is shown for exemplary purposes only. Any other suitable arm mechanism or drive mechanism may be used either alone or in combination. For example, multiple direct-drive modules according to one or more embodiments of this invention may be utilized in a single robotic manipulator or a robotic manipulator having multiple manipulators or any suitable combination. Here, the modules may be stacked in different planes along substantially the same axis of rotation, located concentrically in substantially the same plane, arranged in a configuration that combines the stacked and concentric arrangements, or incorporated into the robotic manipulator in any other suitable manner.

The vacuum-compatible direct-drive system of one or more embodiments of this invention may comprise a housing and a radial field motor arrangement including a stator and a rotor arranged in the vicinity of the stator so that it may rotate with respect to the stator and interact with the stator through a magnetic field substantially radial with respect to the axis of rotation of the rotor. Alternatively, an axial field motor or a combination radial/axial field motor may be provided, or combinations thereof. The stator may include a set of windings energized by a suitable controller based on the relative position of one rotor with respect to the stator. The rotor may include a set of permanent magnets with alternating polarity.

In the embodiment shown, the housing may separate an atmospheric type environment on the outside of the housing from a vacuum or other non-atmospheric environment inside of the housing. Active components, such as the encoder read head or the stator may be fastened to and/or interface with the housing as will be described, for example, the read head or stator may be pressed into or otherwise fastened to the housing to eliminate conventional clamping components and may be encapsulated in a suitable material, such as vacuum compatible epoxy based potting, to limit out-gassing of the components to the vacuum or other non-atmospheric environment as will be described. Here, the encapsulated component may be in vacuum, atmosphere or any suitable environment where the encapsulation protects the stator from the environment, e.g., prevents corrosion, and facilitates efficient heat removal. The encapsulation may also bond the read head or stator to the housing or other component or sub component, further securing the device with respect to the housing. The wires leading to the windings or other active components of the read head or windings of the stator may pass through an opening of the housing which is sealed by the encapsulation, thus eliminating the need for a separate vacuum feed-through, for example, as will be described with respect to FIG. **2**. Alternatively, the read head or stator may be clamped, bolted or attached in any other suitable manner to the housing, and the wires leading from the atmospheric environment to the windings or other active components of the read head or the windings of the stator may be routed through a vacuum feed-through or passed through the wall of the housing in any other suitable manner, for example, as described with respect to FIGS. **3**A-D.

In FIG. **2**, feed through **202** is shown interfacing with housing **105** where housing **105** may separate a first environment **204** from a second environment **206**. Feed through **202** may interface with active component **208** where active component **208** may have active core **210** and leads **214**. Active core **208** may be encased in closure **212** where closure **212** may be a coating, encapsulation, enclosure or combinations thereof in whole or in part as will be described. Alternately, closure **212** may not be provided. Leads **214** pass through holes **216** of housing **105** and are isolated from housing **105** by potting or isolation material **218**. Here material **218** may be the same as material **212** or may be separately potted or otherwise isolated where material **218** may seal across a pressure gradient between environment **204** and **206** or otherwise.

In FIG. **3**A, feed through **224** is shown interfacing with housing **105** where housing **105** may separate a first environment **204** from a second environment **206**. Feed through **224** may interface with active component **208'** where active component **208'** may have active core **210'** and leads **214'**. Active core **208'** may be encased in closure **212'** where closure **212'** may be a coating, encapsulation, enclosure or combinations thereof in whole or in part as will be described. Alternately, closure **212'** may not be provided. Leads **214'** accept leads **226** that interface with feedthroughs **228** that pass through holes **216** of housing **105** and are isolated from housing **105** by insulated cores **230** where cores **230** are sealed **232** to housing **105**. Here cores **230** have conductive inserts **234** hermetically sealed there to where conductive inserts accepts leads **226** on a first environment side **204** and further accept leads **236** on a second environment side **206**. Here, cores **230** in combination with inserts **234** may seal across a pressure gradient between environment **204** and **206** or otherwise. In the embodiment disclosed, active components **208**, **208'** may be any suitable component, for example, a read head, winding or any suitable active component. Alternately, the pin (insert **234**) may be sealed with respect to the housing **105**, and the insulating material (core **230**) may provide guidance and electrical insulation. Alternately, lead **226** and the insert **234** may be a single component, eliminating one connection. As will be described, an expandable feed-through may be provided which can be installed from the outside of housing **105** where the design may also accommodate for misalignment due to tolerances between the features in the housing and the features that the feed-throughs connect to in vacuum.

In FIG. **3**B, feed through **240** is shown interfacing with housing **105** where housing **105** may separate a first environment **204** from a second environment **206**. Here feed through **240** has insulated casing **242** and pins **244**. Socket **246** is provided coupled to an electrical connection in the active component in environment **204**. Pins **244** are shown sealed to housing **105** with an o-ring seal where pin **244** has a threaded end allowing coupling to a lug for electrical connection in environment **206**. Socket **246** has tapered portion **248** such that insertion of pin **244** into socket **246** expands socket **216** such that electrical contact is made between pin **244** and socket **246** upon insertion and assembly.

In FIG. **3**C, feed through **240'** is shown interfacing with housing **105** where housing **105** may separate a first environment **204** from a second environment **206**. Here feed through **240'** has insulated casing **242'** and pins **244'**. Socket **246'** is provided coupled to an electrical connection in the active component in environment **204**. Pins **244'** are shown sealed to housing **105** with an o-ring seal where pin **244'** has a threaded end allowing coupling to a lug for electrical connection in environment **206**. Pin **244'** has tapered portion **248'** such that after insertion of pin **244'** into socket **246'**, rotation of a set screw moves an internal pin of pin **244'** to expand pin **244'** such that electrical contact is made between pin **244'** and socket **246'** upon assembly.

In FIG. **3**D, feed through **240"** is shown interfacing with housing **105** where housing **105** may separate a first environment **204** from a second environment **206**. Here feed through **240"** has insulated casing **242"** and sockets **244"**. Pin **246"** is provided coupled to an electrical connection in the active component in environment **204**. Socket **244"** is shown sealed to housing **105** with an o-ring seal where socket **244"** has a threaded end allowing coupling to a lug for electrical connection in environment **206**. Socket **244"** has tapered portion **248"** such that after insertion of socket **244"** onto pin **246"**, rotation of a screw moves an external sleeve of socket **244"** to compress socket **244"** such that electrical contact is made between socket **244"** and pin **246"** upon assembly.

In order to determine the angular position of the driven part of the direct-drive module, e.g., the angular position of the motor rotor with respect to the housing, a position encoder may be incorporated into the direct-drive module. A position encoder track may be coupled to the driven part of the direct-drive module, and a position encoder read-head may be attached to the housing **105** of the direct-drive module, for example as seen in FIGS. **4-7**. Here, the read head may be optical, inductive, or any suitable type of read head for position determination or otherwise.

In one exemplary embodiment as seen in FIG. **4**, the read-head may have a casing **252** sealed to housing **105** with seal **256** with an active component **254** that may be located entirely in the vacuum or other non-atmospheric environment inside of the housing.

In another exemplary embodiment as seen in FIG. **5**, the read-head may have a casing **252'** sealed to housing **105** with seal **256** with an active component **254'** that may be isolated from in the vacuum or other non-atmospheric environment inside of the housing by casing **252'**.

In another exemplary embodiment as seen in FIG. **6**, the read-head may have a casing **252"** sealed to housing **105** with seal **256** with an active component **254"** that may be partially exposed **258** to the vacuum or other non-atmospheric environment while another part **260** of the active component of the read-head may be present in the surrounding atmospheric environment. In this case, the read-head may be located in an opening in the housing of the direct-drive module and sealed with respect to the wall of the housing. The seal **256** may be compressible to allow for adjustment of the read-head with respect to the track. Alternatively, an angular-contact, axial or radial contact type of sealing arrangement may be utilized to provide a larger adjustment range. As another alternative, a flexure, membrane or bellows may be employed to allow for adjustment of the read-head with respect to the track.

In another exemplary embodiment as seen in FIG. **7**, the read-head may have a casing **252'''** sealed to housing **105** with seal **256** with an active component **254'''** that utilizes vacuum-compatible encapsulation, including the described encapsulation alternatives and enhancements to minimize the risk of out-gassing and protects the stator from the environment, e.g., prevents corrosion, and facilitates efficient heat removal, and may be used or two separation walls **262**, **264** may be incorporated, for example, to isolate different portions **266**, **268** of the read head from one or more environment.

FIG. **8** shows an exemplary read head mounting arrangement. As seen in FIG. **9**, the encoder has disk **304** rotationally mounted on axis **306** and read head **302** movably mounted with respect to housing **105** and sealed to housing **105** with seal **256**. Here seal **256** may be an O-ring, flexure or other suitable seal providing read head **302** sufficient movement radially, axially and also angular movement or otherwise with respect to disk **304** and while maintaining a seal, for example, a vacuum seal. Here disk **304** may be of solid construction of metal with a pattern of lines or spaces for inductive sensing by read head **302** or otherwise. Housing **105** has pins **308** that correspond to a mating hole and slot of head **302** such that head **302** is positively located with respect to housing **105** and disk **304** rotationally mounted therein. Screws **310** fasten head **302** to housing **105** where three set screws **312** allow head **302** to be radially adjusted relative to disk **304** and leveled or otherwise adjusted with respect to disk **304**. In this manner, the location of read head **302** with respect to disk **304** may be adjusted without breaking the vacuum environment. In alternate aspects, any suitable locating or leveling features may be provided.

FIG. **11** shows an exemplary read head mounting arrangement. The encoder has disk **304'** rotationally mounted on axis **306** and read head **302'** movably mounted with respect to housing **105** and sealed to housing **105** with seal **256**. Here seal **256** may be an o-ring, flexure or other suitable seal providing read head **302** sufficient movement radially, axially also angular movement or otherwise with respect to disk **304** and while maintaining a seal, for example, a vacuum seal. Here disk **304** may be of opaque construction of glass or otherwise with a pattern of lines or spaces for optical sensing by read head **302'** or otherwise. Housing **105** has pins **303** shown in FIG. **10** that correspond to a mating slot of head **302'** such that head **302'** is positively located with respect to housing **105** and disk **304'** rotationally mounted therein. Screws **310** fasten with vertical sloes of head **302'** to housing **105** where three set screws **312** allow head **302** to be radially adjusted relative to disk **304** and leveled or otherwise adjusted with respect to disk **304**. Eccentrics **314** are further provided rotationally coupled to housing **105** and engaging mating horizontal slots of read head **302'** such that the location of head **302'** with respect to disk **304'** may be axially adjusted. In this manner, the location of read head **302'** with respect to disk **304'** may be adjusted without breaking the vacuum environment. In alternate aspects, any suitable locating or leveling features may be provided.

FIGS. **12-19** show various combinations of separation walls with respect to motor **108**. Here, as will be described, the separation wall may form an encapsulation, separation, vacuum or gas barrier, for example, to isolate two or more areas or environments. Here motor **108** is shown in partial section and may be exemplary where in alternate embodiments, any suitable motor, combination of motors and/or combination of separation wall(s) may be provided. In FIG. **12**, motor **108** has stator **352** and rotor **354** each of which may have any suitable combination of core(s), magnet(s), winding(s) or otherwise. Separation wall **356** may be a thin walled tubular metal structure that separates environment **204** from that of environment **206** and separates rotor **354** from stator **352**. Alternately, separation wall **356** may be a coating, plating, molded portion, formed portion and having any shape or any suitable separation wall or combination of separation wall (s) and wall type(s). Further, separation wall **356** may be integrally formed as part of housing **105** or may be separate from housing **105**.

In FIG. **13**, motor **108** has stator **352** and rotor **354** each of which may have any suitable combination of core(s), magnet(s), winding(s) or otherwise. Separation wall **356** may be a thin walled tubular metal structure that separates environment **204** from that of environment **206** and separates rotor **354** from stator **352**. Separation wall **358** may further be a thin walled tubular metal structure that separates environment **204** from that of environment **206**. Alternately, separation walls **356**, **358** may be any suitable shape, for example separations walls **356**, **358** may form a partial or complete enclosure enclosing stator **352** such that a third environment **360** within the enclosure is formed isolated from environment **204** and/or environment **206**. Alternately walls **356**, **358** may be a coating, plating, molded portion, formed portion having any shape or any suitable separation wall or combination of separation wall(s) and wall type(s). Further, one or more of separation wall **356**, **358** may be integrally formed as part of housing **105** or may be separate from housing **105**.

In FIG. **14**, motor **108** has stator **352** and rotor **354** each of which may have any suitable combination of core(s), magnet(s), winding(s) or otherwise. Separation wall **356** may be a thin walled tubular metal structure that separates environment **204** from that of environment **206**. Alternately, separation wall **356** may be a coating, plating, molded portion, formed portion and having any shape or any suitable separation wall or combination of separation wall(s) and wall type(s). Further, separation wall **356** may be integrally formed as part of housing **105** or may be separate from housing **105**.

In FIG. **15**, motor **108** has stator **352** and rotor **354** each of which may have any suitable combination of core(s), magnet(s), winding(s) or otherwise. Separation wall **356** may be a thin walled tubular metal structure that separates environment **204** from that of environment **206** where stator **352** is exposed to both environment **204** and **206** and forms a portion of wall **356**. Alternately, separation wall **356** may be a coating, plating, molded portion, formed portion and having any shape or any suitable separation wall or combination of separation wall(s) and wall type(s). Further, separation wall **356** may be integrally formed as part of housing **105** or may be separate from housing **105**.

In FIG. **16**, motor **108** has stator **352** and rotor **354** each of which may have any suitable combination of core(s), magnet(s), winding(s) or otherwise. Separation wall **356** may be a thin walled tubular metal structure that separates environment **204** from that of environment **206** where stator **352** is exposed to both environment **204** and **206** with a portion of wall **356** separating a portion **362** of stator **352** from another portion **364** of stator **352**. Alternately, separation wall **356** may be a coating, plating, molded portion, formed portion and having any shape or any suitable separation wall or combination of separation wall(s) and wall type(s). Further, separation wall **356** may be integrally formed as part of housing **105** or may be separate from housing **105**.

In FIG. **17**, motor **108** has stator **352** and rotor **354** each of which may nave any suitable combination of core(s), magnet(s), winding(s) or otherwise. Separation wall **356** may be a thin walled tubular metal structure that separates environment **204** from that of environment **206** where stator **352** is exposed to both environment **204** and **206** with a portion of wall **356** separating a portion **366** of stator **352** from another portion **368** of stator **352**. Alternately, separation wall **356** may be a coating, plating, molded portion, formed portion and having any shape or any suitable separation wall or combination of separation wall(s) and wall type(s). Further, separation wall **356** may be integrally formed as part of housing **105** or may be separate from housing **105**.

In FIG. **18**, motor **108** has stator **352** and rotor **354** each of which may have any suitable combination of core(s), magnet(s), winding(s) or otherwise. Separation wall **356** may be a thin wailed tubular metal structure that separates environment **204** from that of environment **206** and separates rotor **354** from a portion of stator **352**. Separation wall **358** may further be a thin walled tubular metal structure that separates environment **204** from that of environment **206**. Alternately, separation walls **356**, **358** may be any suitable shape, for example separation walls **356**, **358** may form a partial or complete enclosure enclosing stator **352** such that a third environment **360** within the enclosure is formed isolated from environment **204** and/or environment **206**. Stator **352** is shown having a first portion **370** in environment **204**, second portion **372** in environment **360** and third portion **374** in environment **206**. Alternately walls **356**, **358** may be a coating, plating, molded portion, formed portion having any shape or any suitable separation wall or combination of separation wall(s) and wall type(s). Further, one or more of separation wall **356**, **358** may be integrally formed as part of housing **105** or may be separate from housing **105**.

In FIG. **19**, motor **108** has stator **352** and rotor **354** each of which may have any suitable combination of core(s), magnet(s), winding(s) or otherwise. Separation wall **356** may be a thin walled tubular metal structure that separates environment **201** from that of environment **206** where stator **352** is exposed to both environment **204** and **206** and forms a portion of wall **356**. Separation wall **358** may be a thin walled tubular metal structure that separates environment

204 from that of a portion of stator **352** where stator **352** is exposed to both environment **204** and **206** and forms a portion of wall **356**. Alternately, separation wall **356** may be a coating, plating, molded portion, formed portion and having any shape or any suitable separation wall or combination of separation wall(s) and wall type(s). Further, separation wall **356** may be integrally formed as part of housing **105** or may be separate from housing **105**. In alternate aspects, one or more of the features may be combined, for example, one or more of the features of embodiments of FIGS. **12-23** may be combined in any suitable arrangement or combination.

FIG. **20** shows an example of a stator **352** and rotor **354**. Stator **352** may have a toothed (slotted) iron core, which may provide desirably high torque constant and efficiency. Alternately, stator **352** of the vacuum-compatible drive module may be of a toothless (slotless) design, which may provide desirably low level of cogging. Alternatively, stator **352** of the vacuum-compatible drive module may be of an ironless (coreless) design. Alternately, rotor **354** and stator **352** may be any suitable rotor or stator. Stator **352** may be encapsulated with encapsulation **402** that may be vacuum compatible epoxy with a filler or any suitable encapsulation. The encapsulation may completely or partially surround and encapsulate stator **352**. For example, a metal or any other suitable material that for example has good heat transfer or other desired properties forming ring **404** may be provided in contact with housing **105** while a portion (or none) of encapsulation **402** is or may also be in contact with housing **105**. Alternately, encapsulation **402** may not be in contact with housing **105**, for example, where stator **352**, ring **404** and encapsulation **402** may be formed as a discrete assembly and subsequently installed in housing **105**. Here stator **352** may have ring **404** pressed or otherwise fastened there on and being subsequently potted with encapsulation **402**. Encapsulation **402** may be performed by evacuating a mold with stator **352** and/or ring **404** therein and introducing a liquid resin therein to form the external envelope of encapsulation **402**. Here, a portion of the ring, stator or other suitable component may or may not form a portion of the mold. Alternately and as will be shown, an integral enclosure may form the mold all or in part that defines the volume of the encapsulation. When formed as an assembly independent of housing **105**, the assembly **352**, **404**, **402** may then be assembled to housing **105** by a press fit or other suitable fastening. Here, heat may be transferred from the windings and laminations or core of stator **352** and through encapsulation and/or ring **404** to be dissipated through housing **105**. Here, for example, stator **352** may have pressed or otherwise fastened by fasteners, adhesive or otherwise fastened ring **404** in contact with housing **105** where fastening the ring to the stator and/or housing is such that that there is sufficient contact with the stator and/or the housing to provide a sufficient heat transfer path from the stator to the ring and to the housing or other sinking source. Encapsulation **402** may be integrally molded with housing **105** and stator **352** or separately molded, for example as an assembly with stator **352**, ring **404** as an assembly to be installed in housing **105** as described or otherwise. Ring **404** may further have axial holes **424** and trapezoidal cuts **420** formed to facilitate bonding of encapsulation **402** and resolution of internal stresses such as due to thermal expansion of the potting material. Here, the function of the ring **404** may be to provide a path to remove heat from the stator **352** and transfer it to the housing **105**, which may be cooled, for example, externally or otherwise cooled, while keeping a continuous protection barrier around the stator, for example, where a stator may be formed from laminates, ring **404** forms a continuous protection barrier as compared to non continuous laminations. Alternately, encapsulation **402** and housing **105** may be made of the same material, for example, where housing **105** and encapsulation **402** are molded as a unitary structure with stator encapsulated in whole or in part there in a unitary material **105** and **402**. Here, encapsulation **402** may form a separation barrier and may provide protection from the environment, e.g., to prevent corrosion, and/or facilitate heat removal as previously described. Although FIG. **20** shows ring **404** used in various combinations with stator **352**, encapsulation **402** and housing **105**, alternately, encapsulation **402** may apply to embodiments with or without the ring, housing **105** or otherwise as a unitary structure with or without another component or otherwise. Accordingly, all such variations are embraced.

As shown in FIG. **21**, the exposed surfaces of the stator encapsulation **402** of the vacuum-compatible direct-drive module may be coated either completely or in part with coating **406**, e.g., utilizing electroless nickel plating, to eliminate or minimize exposure of the potting material used for the encapsulation of the stator to the vacuum, atmospheric, sub-atmospheric, pressurized, or other non-atmospheric environment to further reduce the risk of outgassing. Here, coating **406** may form a separation barrier as previously described. Alternatively, as seen in FIG. **22**, one or more thin sheets of protective material **408**, **410**, **412**, e.g., made of stainless steel or another suitable material, may be bonded to the encapsulation of the stator, for example, in the potting process, as shown in FIG. **22**. This may limit the exposure of the potting material to the seams between the thin sheets of protective material. Here, potting material **402** may form a seal between sheets **408**, **412**, **410** or the sheets may be otherwise sealed, for example, by welding, brazing, soldering or with any suitable static seal, such as o-rings or otherwise. Here, sheets **408**, **410**, **412** and ring **404** may form a separation barrier as previously described. Here, the stator may be enclosed in a thin cage or enclosure bonded to the potting material, for example, in the potting process. The thin cage or enclosure may be, e.g., welded from thin sheets of stainless steel.

In FIG. **23**, an enclosure, for example of machined or otherwise formed aluminum or stainless steel or other suitable material is provided having sleeve **414**, lower casing **416** and upper casing **418**. Each may be sealed by potting **402** or otherwise sealed, for example, by welding, brazing, soldering or with any suitable static seal, such as o-rings or otherwise. Here, potting **402** may not be provided and where the interior volume of the casing may form an intermediate environment, for example, environment **360** or otherwise. Alternately, more or less or partial casing(s) may be provided, for example, where the windings of a stator are potted but the teeth are not or otherwise. Here, a small gap may be provided between the stator and the rotor, which preserves the torque output and efficiency of conventional motor designs. Here, with radial-field motors, a separation layer may be incorporated into the stator(s), for example, by the means of coating, bonding or by any other suitable method. As another alternative, the stator(s) may be molded or otherwise packaged in a material compatible with and resistant to vacuum or any other environment the stator(s) may be subject to. As a further alternative, the stator may be encapsulated in a vacuum tight vessel as seen in FIG. **23**. Similarly, the rotor may be coated, carry a bonded protection layer, molded or packaged in a protective material, encapsulated in a vacuum tight vessel or otherwise protected from the environment it may operate in.

The exposed surfaces of the stator encapsulation may be coated, for example, as in FIG. **21**, e.g., utilizing electroless nickel plating, to eliminate or minimize exposure of the potting material used for the encapsulation of the stator to the vacuum or other non-atmospheric environment to further reduce the risk of out-gassing. Alternatively, thin sheets of protective material, for example, as seen in FIG. **22**, e.g., made of stainless steel, may be bonded to the encapsulation of the stator, preferably in the potting process, as shown in FIG. **22**. This limits the exposure of the potting material to the seams between the thin sheets of protective material. As another alternative, as shown in FIG. **23**, the stator may be enclosed in a thin enclosure bonded to the potting material, preferably in the potting process. The enclosure may be, e.g., welded from thin sheets of stainless steel. As yet another alternative, a thin separation wall, for example, in the form of a disk **412**, may be present between the stator and rotor of the axial-field motor. The stator may be pressed, bonded, clamped, bolted or attached in any other suitable manner to the housing of the direct-drive module as seen in FIG. **20**.

The above described radial, axial or combination radial-axial-field motor may be of coreless (ironless) design. In another example embodiment with a motor arrangement, a coreless stator with windings and two rotors with magnets, each rotor on one side of the stator, may be utilized. Alternatively, the stator may include an iron core as the passive magnetic forces exerted on the iron core by the two rotors may be balanced. Yet another example embodiment with a motor arrangement may include two stators with windings and a single rotor with magnets sandwiched between them. Vacuum-compatible encapsulation, including the above described encapsulation alternatives and enhancements to minimize the risk of out-gassing and/or enhance heat transfer, may be used or two or more separation walls may be incorporated into these example embodiments as described.

In another embodiment of the vacuum-compatible direct-drive system of this invention, the motor configuration(s) utilized in the above examples may be replaced by a different motor topology, including without limitation a hybrid-field (radial-axial) configuration. For instance, the stator(s) and rotor(s) may feature a conical, convex v-shaped, concave v-shaped, convex semicircular or concave semicircular profile, any combination of conical, v-shaped and semicircular profiles, or any other suitable profile, resulting in a substantially uniform gap or gaps between the stator(s) and rotor(s). Vacuum-compatible encapsulation, including the above described encapsulation alternatives and enhancements to minimize the risk of out-gassing, may be used, or a separation wall of a suitable shape may be present in the gap(s). Outer-stator-inner-rotor and inner-stator-outer-rotor configurations may be used. In an alternate embodiment, the entire housing **105** may be formed or otherwise molded where the stator may be incorporated directly into the molded housing. As an alternative to molding, casting or spray forming or any suitable fabrication of any suitable alternative material may be provided. In alternate embodiments, any suitable number of winding phases, distributed or otherwise may be provided within the stator. In alternate embodiments, for example, with respect to the passive magnetless rotor or any suitable rotor described, the rotor may not be solid, for example, where the rotor is laminated in some fashion but vacuum compatible to reduce losses.

As seen in FIG. **24**, the vacuum-compatible direct-drive system may employ a radial field motor arrangement **108** including a wound brushless stator **352** and a rotor **354** with magnets **452** arranged in the vicinity of the stator so that it may rotate with respect to the stator and interact with the stator through a magnetic field substantially radial with respect to the axis of rotation **306** of the rotor. The stator may have windings **454**, core **456** and backing ring **404**. Alternately, stator **352** may be coreless where the coreless stator may consist of a set of windings energized by a suitable controller based on the relative position of the rotor with respect to the stator. The rotor **354** may include a set of permanent magnets **452** with alternating polarity. As described, the stator may be encapsulated in a suitable material, such as vacuum compatible epoxy based potting, to limit out-gassing of the stator components to the vacuum or other non-atmospheric environment. The encapsulation may also bond the stator to the housing of the direct-drive module, further securing the stator with respect to the housing as seen in FIG. **20**. The wires leading to the windings of the stator may pass through an opening of the housing which is sealed by the encapsulation as seen in FIG. **2**, thus eliminating the need for a separate vacuum feed-through as seen in FIG. **3**. Alternatively, the wires leading from the atmospheric environment to the windings of the stator of the radial field motor may be routed through a vacuum feed-through or passed through the wall of the housing of the direct-drive module in any other suitable manner.

As seen in FIG. **25**, motor **108** may be motor **108'** that may be a hybrid design having toothed passive rotor **458**, stator phase A **460** and stator phase B **462** separated by ring permanent magnet **464**. A suitable example may be found in U.S. Pat. No. 5,834,865 entitled "Hybrid Stepping Motor" which is hereby incorporated by reference in its entirety. Alternately, the ring magnet may be provided within rotor **458**. As shown, a solid non magnetic passive rotor, for example, not containing permanent magnets and having high permeability/saturation and low coercivity, for example, of 400 series stainless steel having no magnets may be provided to reduce outgassing where the stator portion(s) may be provided with one or more separation walls as previously described. Such arrangement minimizes exposed materials to vacuum, for example, where the magnets are not exposed to vacuum. Similarly, such a nonmagnetic passive rotor, not containing permanent magnets, may be used in combination with any suitable stator, such as any of the exemplary embodiment stators or otherwise disclosed embodiments.

As seen in FIG. **26**, motor **108** may be motor **108"** that may be an axial field design having rotor **470** with magnets **472**, and stator **474** with core **476** and windings **478**. Alternately, the magnets may be provided within the stator.

As seen in FIG. **27**, motor **108** may be motor **490** that may be a brushless design having a passive rotor **494** and stator **492** as will be described in greater detail. Here stator **492** may have core **496** (solid or laminated), windings **498** and magnets **500**. As shown, a solid nonmagnetic passive rotor as described, for example, of 400 series stainless steel having no magnets may be provided to reduce outgassing where the stator portion(s) may be provided with one or more separation walls as previously described. Such arrangement minimizes exposed materials to vacuum, for example, where the magnets are not exposed to vacuum. Similarly, such a nonmagnetic passive rotor, not containing permanent magnets, may be used in combination with any suitable stator, such as any of the exemplary embodiment stators or otherwise disclosed embodiments.

As seen in FIGS. **28** and **29**, motor **502** is provided having features similar to that shown in FIG. **27**. A liner variant may be found in U.S. Pat. No. 7,800,256 entitled "Electric Machine" which is hereby incorporated by reference in its entirety. Motor **502** has stator **504** and toothed passive rotor **506**. Rotor **506** may be 400 series stainless steel or any suitable material that can channel the magnetic flux from stator **504** but without permanent magnets. Stator **504** may be separated from rotor **506** by one or more separation walls **508**, **510** as previously described where walls **508**, **510** may be 300 series stainless steel, aluminum or other suitable material that allows field interaction between rotor **506** and stator **504**. Stator **504** has salient windings **512** on teeth **514** with two alternating magnets **516**, **518** on each tooth and where magnets on adjacent teeth have matching polarity with respect to the tooth as shown. Alternately, distributed windings may be provided. Flux is selectively directed by a given winding to one of the two magnets on the tooth depending on the polarity of the winding. Flux is directed from each tooth through the teeth on the rotor to and adjacent tooth of the stator to selectively commutate the motor. In alternate aspects, any suitable motor having a non magnetic passive rotor may be provided.

As seen in FIGS. **30** and **31**, motor **552** is provided having features similar to that shown in FIGS. **27**, **28** and **29**. Motor **552** has stator **554** and toothed passive rotor **556**. Rotor **556** may be 400 series stainless steel or any suitable material that can channel the magnetic flux from stator **554** but without permanent magnets. Stator **554** may be separated from rotor **556** by one or more separation walls **558**, **560** as previously described where walls **558**, **560** may be 300 series stainless steel, aluminum or other suitable material that allows field interaction between rotor **556** and stator **554**. Stator **554** has salient tangentially wound windings **562** between teeth **564** with two alternating magnets **566**, **568** on each tooth and where magnets on adjacent teeth have matching polarity with respect to the tooth as shown. Alternately, distributed windings may be provided. Flux is selectively directed by a given winding to one of the two magnets on the tooth depending on the polarity of the winding. Flux is directed from each tooth through the teeth on the rotor to and adjacent tooth of the stator to selectively commutate the motor. In alternate aspects, any suitable motor having a non magnetic passive rotor may be provided.

As seen in FIGS. **32** and **33**, motor **602** is provided having features similar to that shown in FIG. **27**. A similar device may be found in U.S. Pat. No. 7,898,135 entitled "Hybrid Permanent Magnet Motor" and U.S. Patent Publication No. 2011/0089751 A1 entitled "Parallel Magnetic Circuit Motor" both of which are hereby incorporated by reference in its entirety. Motor **602** has stator **604** and toothed passive rotor **606**. Rotor **606** may be 400 series stainless steel or any suitable material that can channel the magnetic flux from stator **604** but without permanent magnets. Stator **564** may be separated from rotor **606** by one or more separation walls **608**, **610** as previously described where walls **608**, **610** may be 300 series stainless steel, aluminum or other suitable material that allows field interaction between rotor **606** and stator **604**. Stator **604** has salient tangential windings **612** on core **614**, with each core having two teeth and with two alternating magnets **616**, **618** on each core and where magnets on adjacent cores have opposing polarity with respect to the core as shown. Alternately, distributed windings may be provided. Flux is selectively directed by a given winding to one of the two teeth on the core depending on the polarity of the winding. Flux is directed from each tooth through the teeth on the rotor to an adjacent tooth of the stator to selectively commutate the motor. In alternate aspects, any suitable motor having a non magnetic passive rotor may be provided.

As seen in FIGS. **34** and **35**, motor **652** is provided having features similar to that shown in FIG. **27**. A liner variant may be found in U.S. Pat. No. 7,800,256 entitled "Electric Machine" which is hereby incorporated by reference in its entirety. Motor **652** has stator **654** and toothed passive rotor **656**. Rotor **656** may be 400 series stainless steel or any suitable material that can channel the magnetic flux from, stat or **504** but without permanent magnets. Stator **654** may be separated from rotor **656** by one or more separation walls **658**, **660** as previously described where walls **658**, **660** may be 300 series stainless steel, aluminum or other suitable material that allows field interaction between rotor **656** and stator **654**. Stator **654** has salient windings **662** on teeth **664** with two alternating magnets **666**, **668** on opposing sides of the core of each tooth and where magnets on cores of adjacent teeth have opposing polarity with respect to the tooth as shown. Alternately, distributed windings may be provided. Flux is selectively directed by a given winding to the tooth depending on the polarity of the winding. Flux is directed from each tooth through the teeth on the rotor to and adjacent tooth of the stator to selectively commutate the motor. In alternate aspects, any suitable motor having a non magnetic passive rotor may be provided.

As seen in FIGS. **36** and **37**, motor **702** is provided having features similar to that shown in FIG. **27**. A liner variant may be found in U.S. Pat. No. 7,800,256 entitled "Electric Machine" which is hereby incorporated by reference in its entirety. Motor **702** has stator **704** and toothed passive rotor **706**. Rotor **706** may be 400 series stainless steel or any suitable material that can channel the magnetic flux from stator **504** but without permanent magnets. Stator **704** may be separated from rotor **706** by one or more separation walls **708**, **710** as previously described where walls **708**, **710** may be 300 series stainless steel, aluminum or other suitable material that allows field interaction between rotor **706** and stator **704**. Stator **704** has salient windings **712** on split teeth **714** with a magnet **716** splitting each tooth and where magnets on adjacent teeth have opposing polarity with respect to the tooth as shown. Alternately, distributed windings may be provided. Flux is selectively directed by a given winding to one of the two split portions of the tooth depending on the polarity of the winding. Flux is directed from each tooth through the teeth on the rotor to and adjacent tooth of the stator to selectively commutate the motor. In alternate aspects, any suitable motor having a non magnetic passive rotor may be provided.

An example substrate transport apparatus may comprise a drive section comprising a first motor, where the first motor comprises a stator and a passive rotor; and a first movable arm assembly connected to the first motor. The substrate transport apparatus may be configured for the first movable arm assembly to be positionable in a vacuum chamber **4** (see FIG. **1**) with the passive rotor being in communication with an environment inside the vacuum chamber.

The first motor may be a radial field motor arrangement. The stator may comprise a coil and a permanent magnet. The passive rotor may comprise no coil and no permanent magnet. The passive rotor may comprise a stainless steel one piece member. The first motor may be a linear motor arrangement. The passive rotor may comprise a tooth surface facing the stator. The substrate transport apparatus may further comprise a gas barrier located between the stator and the passive rotor to separate the environment at the passive rotor (environment in chamber **4** and extending into the motor region of the drive **10**) from an environment at the stator (such as atmospheric **6**). The gas barrier may comprise at least one separation wall. The separation wall may comprise a stainless steel, or aluminum, or other material that allows magnetic field interaction between the passive rotor and the stator. The gas barrier may comprise a housing surrounding substantially entirely around the stator. The housing may comprise an encapsulation material surrounding the stator. The encapsulation material may comprise an overmolded polymer material which has been molded onto the stator.

An example method may comprise providing a substrate transport apparatus comprising a drive section and a first movable arm assembly connected to the drive section, where the drive section comprises a motor comprising a stator and a passive rotor; and connecting the substrate transport apparatus to a vacuum chamber, where the first movable arm assembly is positioned in the vacuum chamber with the passive rotor being in communication with an environment inside the vacuum chamber.

Providing the substrate transport apparatus comprises the stator may include a coil and a permanent magnet, and the passive rotor may have no coil and no permanent magnet. The method may further comprise locating a gas barrier between the stator and the passive rotor to separate the environment at the passive rotor from an environment at the stator. The gas barrier may comprise at least one separation wall being located between the stator and the passive rotor. The gas barrier may comprise encapsulating the stator with an encapsulation material. The gas barrier may comprise enclosing the stator inside an enclosure, where a wall of the enclosure is located in a gap between the stator and the passive rotor.

An example substrate transport apparatus may comprise a drive section comprising a first motor, where the first motor comprises a stator and a passive rotor; a first movable arm assembly connected to the first motor; and a gas barrier located in a gap between the stator and the passive rotor to separate an environment at the passive rotor from an environment at the stator.

It should be understood that the foregoing description is only illustrative. Various alternatives and modifications can be devised by those skilled in the art. For example, features recited in the various dependent claims could be combined with each other in any suitable combination(s). In addition, features from different embodiments described above could be selectively combined into a new embodiment. Accordingly, the description is intended to embrace all such alternatives, modifications and variances which fall within the scope of the appended claims.

What is claimed is:

1. An apparatus comprising:

a position sensor read head;

a casing connected to the read head, where the casing is configured to be sealingly connected to a motor assembly housing to seal an aperture through the housing for keeping an environment inside the housing separated from an environment outside the housing at the aperture, where the casing is configured to isolate at least a portion of the read head from the environment inside the housing, and where the read head is configured to sense a reference member in the environment inside the housing; and

an adjustable connector comprising the casing, where the adjustable connector is configured to adjustably connect the read head to the motor assembly housing and lock a location of the read head relative to the motor assembly housing at one of a number of different locations, where the adjustable connector is configured to seal the aperture through the housing for keeping the environment inside the housing separated from the environment outside the housing at the aperture, where the adjustable connector is configured to allow position of the read head on the housing to be adjusted from outside the housing, where the adjustable connector is configured to allow the read head to be radially adjusted on the housing to the number of different locations without breaking the seal with the housing at the aperture.

2. An apparatus as in claim **1** further comprising a seal on the casing to surround the aperture and sealingly connect the casing to the motor assembly housing.

3. An apparatus as in claim **1** where the casing is configured to completely isolate the read head from the environment inside the housing when the casing is mounted to the housing.

4. An apparatus as in claim **1** where the casing is configured to not isolate an active component of the read head from the environment inside the housing when the casing is mounted to the housing, and configured to isolate another part of the read head from the environment inside the housing when the casing is mounted to the housing.

5. An apparatus as in claim **1** where the adjustable connector comprises a removable connector for removably connecting the casing to the motor assembly housing.

6. An apparatus as in claim **1** where the read head is an inductive read head, and where the apparatus comprises the reference member as a disk of solid metal configured to be sensed by the read head.

7. An apparatus as in claim **1**, where the casing comprises metal which is configured to be sealingly connected to the housing with a compliant seal.

8. An apparatus as in claim **1** where the adjustable connector is configured to axially allow the read head to be adjusted on the housing without breaking the seal with the housing at the aperture.

9. An apparatus as in claim **1** where the read head is configured to project through the aperture from an outside of the housing, past an inside surface of the housing, with an active component of the read head located inside the housing at least partially past the inside surface of the housing.

10. An apparatus as in claim **1** where the casing comprises a head section which is larger than the aperture and a shaft section which extends through the aperture, where the head section is located configured to be mounted to an exterior side of the housing.

11. An apparatus comprising:

a position sensor read head; and

an adjustable connector configured to adjustably connect the read head to a motor assembly housing and lock a location of the read head relative to the motor assembly housing at one of a number of different locations, where the adjustable connector is configured to seal an aperture through the housing for keeping an environment inside the housing separated from an environment outside the housing at the aperture, where the read head is configured to read a reference member located in the environment inside the housing, where the adjustable connector is configured to allow position of the read head on the housing to be adjusted from outside the housing, and where the adjustable connector is configured to allow the read head to be radially adjusted relative to the housing and locked at one of the number of different radial locations without breaking the seal with the housing at the aperture.

12. An apparatus as in claim **11** where the adjustable connector comprises a casing connected to the read head and fasteners configured to clamp a portion of the casing towards the housing, where the adjustable connector is configured to allow the casing to be adjusted on the housing to thereby adjust the read head relative to the housing.

13. An apparatus as in claim **11** where the adjustable connector is configured to allow the location of read head with respect to the reference member to be adjusted without breaking the seal at the aperture between the environment inside the housing and the environment outside the housing.

14. An apparatus as in claim **11** where the adjustable connector comprises a seal configured to surround the aperture at an exterior side of the housing, and where the adjustable connector is also configured to allow movement axially and/or angular relative to the reference member while maintaining the seal at the aperture between the environment inside the housing and the environment outside the housing.

15. An apparatus as in claim **11** where the adjustable connector comprises a casing connected to the read head, where the casing comprises holes configured to receive projections of the housing, where the holes are larger than the projections to allow the casing to move on the projections, and further comprising fasteners to lock the position of the casing on the housing.

16. An apparatus as in claim **11** comprising a casing connected to the read head, where the casing is configured to be sealingly connected to the motor assembly housing to seal the aperture through the housing for keeping the environment inside the housing separated from the environment outside the housing at the aperture, and where the casing is configured to isolate at least a portion of the read head from the environment inside the housing.

17. An apparatus as in claim **11** where the read head is an inductive read head, and where the apparatus comprises the reference member as a disk of solid metal configured to be sensed by the read head.

18. An apparatus as in claim **11** where the adjustable connector is a removable connector including a casing on the read head, where the removable connector is configured to removably connect the read head at the aperture through the motor assembly housing, where the connector plugs the aperture through the housing and to seal with the motor assembly housing for keeping the environment inside the housing separated from the environment outside the housing at the aperture, and where the removable connector is configured to allow the read head to be unplugged from the housing by pulling the read head outward from the aperture.

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